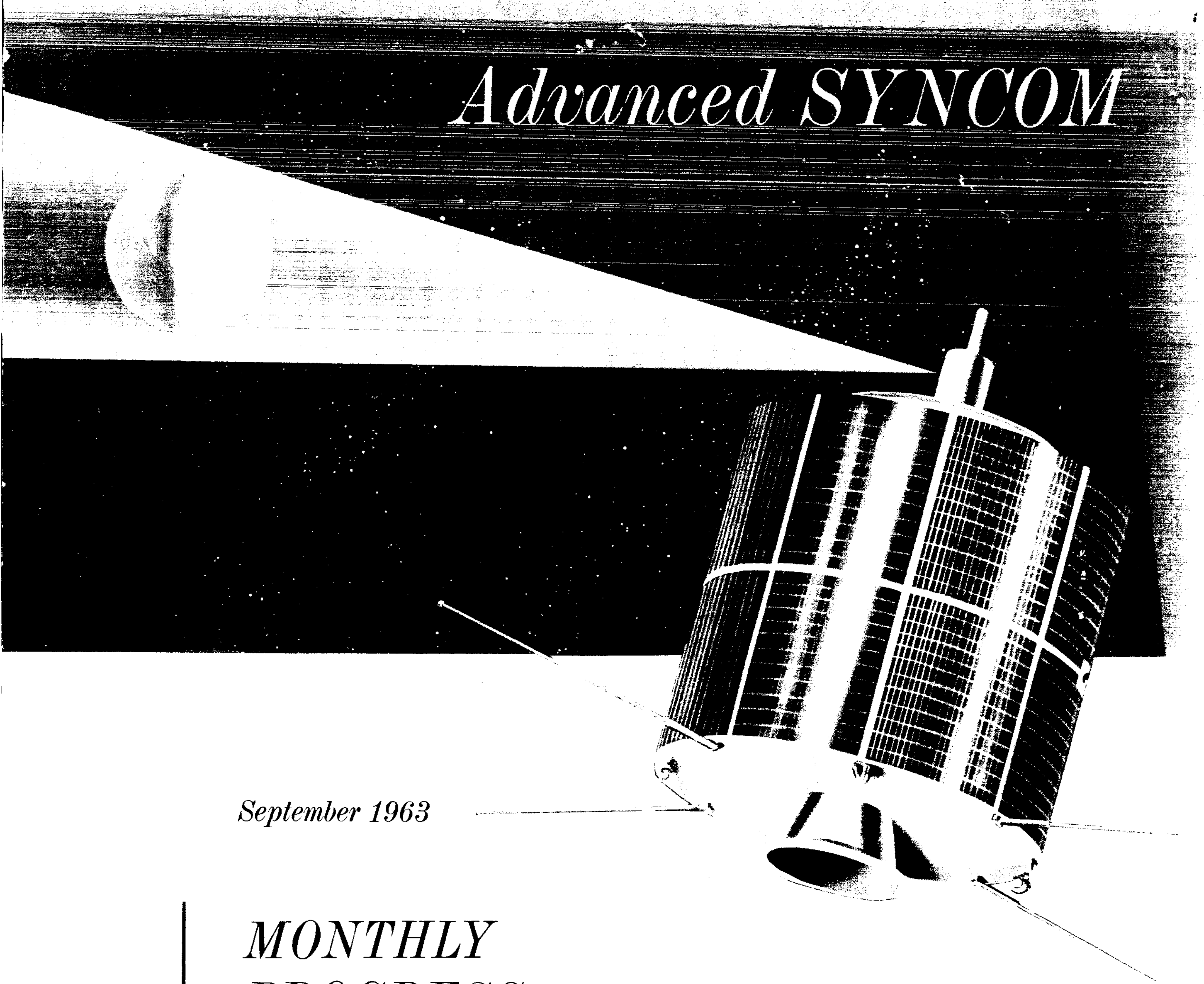


Advanced SYNCOM

September 1963

MONTHLY PROGRESS REPORT

NASA Contract 5-2797
SSD 31074R

HUGHES
HUGHES AIRCRAFT COMPANY
SPACE SYSTEMS DIVISION

HUGHES AIRCRAFT COMPANY

AEROSPACE GROUP

SPACE SYSTEMS DIVISION

CULVER CITY, CALIFORNIA

12 October 1963

SUBJECT: Advanced Syncom Monthly Progress Report for September 1963

TO: Mr. Robert J. Darcey
Program Manager, Syncom
Goddard Space Flight Center
Code 621
Greenbelt, Maryland

Attached are copies of the Advanced Syncom Monthly Progress Report for September 1963.

A demonstration was conducted which provides experimental evidence that when the transponder operates in the multiple-access mode, a carrier of sufficient magnitude for tracking purposes is available even for the case of full-channel loading. Under the condition equivalent to full-channel loading the carrier level was measured at about 7 db below the no-modulation carrier level. These results show good correlation to the analytical computations provided in the May monthly progress report.

Two propellant exhaustion tests were conducted with the engineering model of the bipropellant system. For these tests the axial motor was modified to change the fuel injector pressure drop to allow continuous firing with adequate chamber durability.

The addendum to this report entitled "System Test Equipment" contains descriptions and specifications for all major items of a ground test station. This document fulfills the ground support test station package requirement of the current contract.

HUGHES AIRCRAFT COMPANY

Paul E. Norsell

Paul E. Norsell
Manager, Systems Development
Advanced Syncom

cc: H. A. Zaret
Goddard Space Flight Center
Code 241.4
Greenbelt, Maryland

Advanced SYNCOM

September 1963

MONTHLY PROGRESS REPORT

•

NASA Contract 5-2797
SSD 31074R

HUGHES

HUGHES AIRCRAFT COMPANY
SPACE SYSTEMS DIVISION

CONTENTS

1. INTRODUCTION

The use of communication satellites is an answer to the need for greatly expanded global communications capability. It has been a major effort of the United States Government and of industry to develop a satellite relay system at the earliest possible time.

Under NASA Goddard Space Flight Center Contract NAS-5-1560, Hughes Aircraft Company developed the Syncom I spacecraft to be orbited by NASA Delta launch vehicles and used in conjunction with Department of Defense Advent ground stations for the performance of inclined synchronous-orbit communication experiments during 1963.

The Syncom I spacecraft has demonstrated that a simple spin-stabilized design is capable of being placed in a synchronous orbit. Its operation will also show that a pulse-jet control system can provide the stationkeeping necessary to maintain this orbit.

Additional important mission objectives of the NASA communication satellite program include demonstration of a "stationary" or equatorial, synchronous orbit, conduct of system orbital life tests, demonstration of new wide-band services on a transoceanic basis, and demonstration of a system accessible to many ground stations.

Under NASA Goddard Space Flight Center Contract NAS-5-2797, Hughes is conducting feasibility studies and advanced technological development for an advanced, stationary, active repeater communication satellite. A Summary Report covered the technical progress achieved during the original contract period and detailed the system configuration resulting from the system studies. A subsequent supplementary report covered further studies made under Modification 2 to the above contract and the accompanying technical direction.

This report covers contractual activities during the month of September 1963.

2. COMMUNICATION SYSTEM DESIGN

FREQUENCY AND PHASE STABILITY ANALYSIS OF THE MULTIPLE-ACCESS SYSTEM

Studies are continuing on the frequency and phase stability problems related to both the ground and spacecraft systems. The prime objective is to determine effects of long term drift and short term phase jitter of the oscillators in the multiple-access system. This analysis will be published in the Summary Report.

SUMMARY OF DEMONSTRATION SHOWING CARRIER REDUCTION IN MULTIPLE-ACCESS MODE

The purpose of this demonstration was to show that, under full modulation conditions, the carrier can be used instead of a beacon. The unmodulated carrier level was measured and then modulated by a continuous 5-megacycle spectrum of noise simulating full modulation; the drop in carrier level was noted.

The configuration used for the demonstration (Figure 2-1) consists basically of:

1) HP-608A signal generator to determine the power level of the modulating noise simulating full modulation

2) Noise source to modulate the carrier

3) HP-431B power meter to monitor the modulating signal

4) Spacecraft electronics under test

5) Panoramic SPA4a spectrum analyzer to monitor the carrier level

6) HP-618 signal generator as a calibrated source with which to compare the carrier level.

Demonstration Procedure

A single test signal from the HP-608A signal generator, adjusted for a peak modulation index of 1.6, determines the noise power level required for full modulation. The reading on the power monitor is noted and the test signal removed.

The unmodulated carrier level is observed on the spectrum analyzer and a signal from the HP-618 generator at the same level and frequency is fed into the spectrum analyzer; the reading on the calibrated dial of the generator, which is equal to the strength of the unmodulated carrier, is noted.

The modulating noise level is then increased until the power monitor indicates the same level as the single test signal. The height of the carrier is noted and the HP-618 generator at the same frequency is again fed into the spectrum analyzer and the dial adjusted until the signal level from the signal generator is the same as the fully modulated carrier. The dial reading equals the modulated carrier level.

Subtracting the dial reading (db) obtained from the unmodulated carrier from that obtained for the modulated carrier gives the drop in carrier level caused by full modulation

Results

The equivalent test signal required to determine the necessary modulating noise level is one in which the ratio of first sideband to carrier at the output is 1.25 (see calculations below). The power monitor reading for the test signal was 1.24 milliwatts. The unmodulated carrier level was -14 dbm.

By removing attenuation at Step Attenuator 1 in the noise source, noise modulation was increased until the power monitor indicated 1.4 milliwatts. (This was the closest level to 1.24 milliwatts attainable due to the discrete steps of the attenuator.) The modulated carrier level was -22 dbm. Therefore, the drop in carrier level was 8 db.

Calculations

For calculating the relative magnitude of sideband to carrier for the test signal, it has already been determined that 40 test tones at a peak modulation index of 0.002 radian per test tone at the output of the phase modulator will simulate full modulation. At the phase modulator $\phi_m = 0.002$ peak radians per test tone. At the output of the multiplier chain $\phi_m = 0.002 \times 2 \times 32 \times 2$ peak radians per test tone = 0.256 peak radians per test tone.

$$\text{Total } \phi \text{ rms} = \sqrt{\left(\frac{0.256}{\sqrt{2}}\right)^2 + \ldots + \left(\frac{0.256}{\sqrt{2}}\right)^2} = \sqrt{40\left(\frac{0.256}{\sqrt{2}}\right)^2} = 1.15 \text{ radians}$$

ϕ equivalent rms = 1.15 radians

ϕ equivalent peak = 1.15 x $\sqrt{2}$ = 1.6 radians

$$\text{Ratio of first sideband to carrier} = \frac{J_1\ (1.6)}{J_o\ (1.6)} = 1.25$$

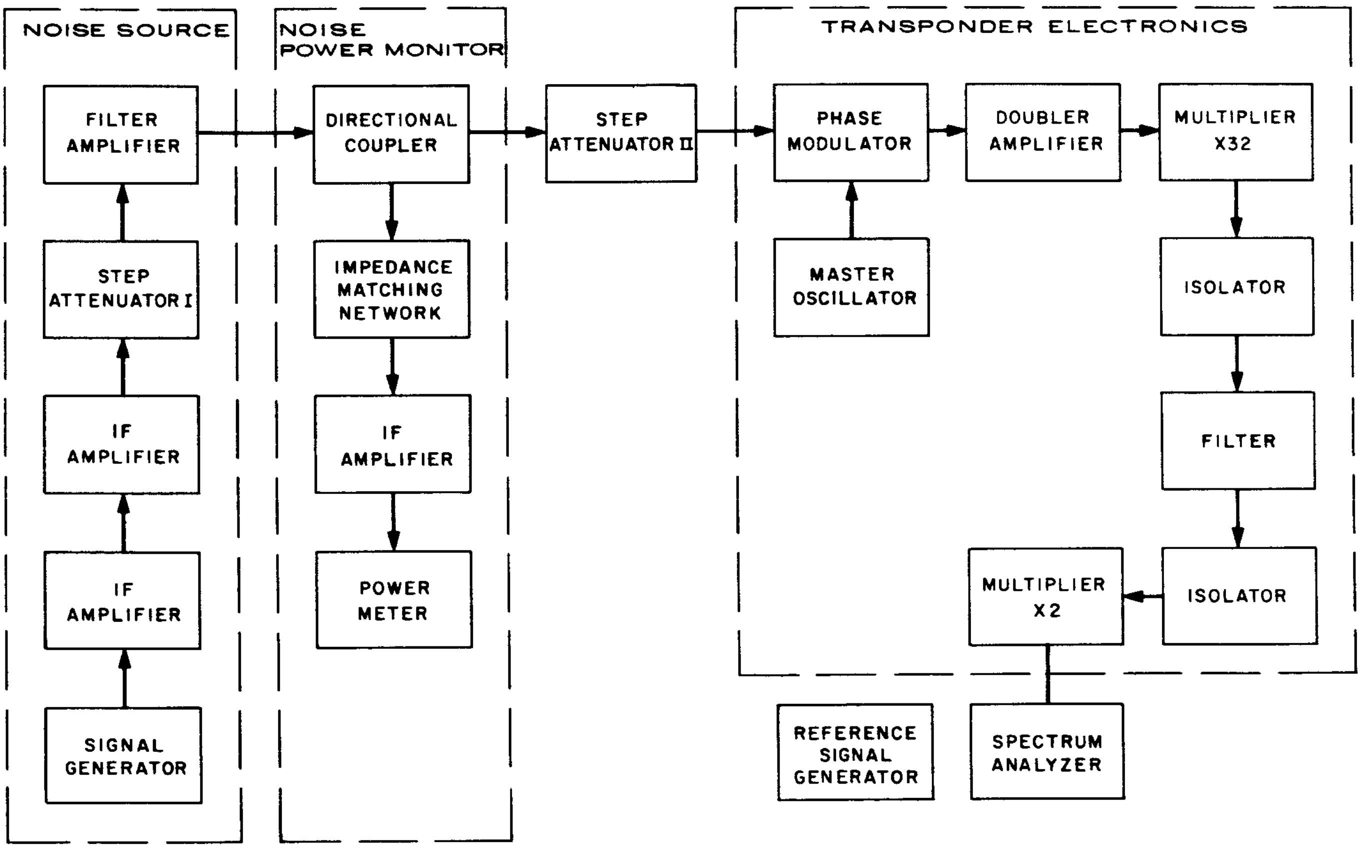


Figure 2-1. Demonstration Setup Block Diagram

3. LAUNCH AND ORBIT ANALYSIS

EMERGENCY PROCEDURES

The August progress report presented a tentative list of correctable failures that may occur during the ascent sequence. The following list delineates the probable sources of failure indication associated with each nominal event in general chronological order of availability. Only those sources marked with an asterisk are sufficient indications that a failure has occurred; the other sources are merely necessary (usually earlier) indications of failure. More quantitative descriptions of the failure indications will be forthcoming as the orbital injection, tracking station, and spacecraft design parameters become more definite. The detailed description of failure mode procedures and data will generally follow the format of the referenced report* where applicable.

TENTATIVE FAILURE INDICATION SOURCES

1) Agena Second Burn Cutoff (Fuel Depletion)

   a) Agena guidance telemetry

   b) FPS-16 data

   c) Range, range rate, and angle data (transponder on)

   d) Minitrack data

   *e) GFSC orbital elements

2) Agena Yaw Maneuver

   a) Agena guidance telemetry

   *b) Spacecraft polarization (before spinup)

   *c) Spacecraft sun angle, ϕ, determination (after spinup)

*D. D. Williams, "Syncom I (A-26) Failure Mode Procedures and Data," Hughes Aircraft Company IDC, January 1963 Revision I, June 1963.

3) Spacecraft Spinup

a) Agena spin rate detection/telemetry

*b) Spacecraft sun sensor/telemetry (spin speed)

c) Spacecraft radial accelerometer (if available)

d) Spacecraft RF spin modulation (pancake or pencil beam)

4) Spacecraft Separation (Tipoff)

a) Agena guidance telemetry

*b) Spacecraft sun angle (ϕ) determination

*c) Polarization angle measurement

5) Apogee Motor Ignition

a) Spacecraft axial accelerometer (if available)

b) Ground observer (weather and local night time permitting)

c) Sun sensor telemetry (spin speed change)

d) Solar panel power modulation (spin speed change)

e) Spacecraft temperature

*f) GSFC orbital elements

6) Spin Axis Orientation

a) Fuel and oxidizer and tank pressure and temperature/telemetry

*b) Spin axis attitude elements (ϕ angle and polarization angle)

7) In-Plane Velocity Correction

a) Fuel and oxidizer and tank pressure and temperature/telemetry

*b) GSFC orbital elements

8) Inclination Correction

a) Fuel and oxidizer and tank pressure and temperature/telemetry

*b) GSFC orbital elements

DYNAMIC ANALYSIS

Axial Jet Induced Nutation

Since the axial jet is operated in a synchronously pulsed mode to generate precession torque pulses and in a continuous (long-pulse) mode to generate a translational force, it is desirable to estimate the maximum nutation angle, θ_{max}, induced by either of the above modes. For a given roll-to-pitch, moment of inertia ratio I_z/I_x, spin speed W_z, and torque level N_o, the value of θ_{max} after continuous axial jet operation may be greater (seven to eight times) than the maximum nutation angle induced by a series of spin synchronous torque pulses. Continuous mode operation of the axial jet will result in the following maximum nutation angles for nominal and limit parameters.

	Nominal (50 percent propellant depletion	Limit (100 percent propellant depletion
ω_z, rpm	100	90
I_z/I_x	1.17	1.11
I_z, slug-ft^2	62.8	55.83
N_o, ft-lb	10	6.5 (~3-pound thrust)
θ_{max}, degrees	0.97	1.36

θ_{max} was computed using

$$\theta_{max} = \frac{2N_o}{\omega_z^2\left(\frac{I_z}{I_x} - 1\right) I_z}$$

The presence of the nutation damper will cause these numbers to be reduced asymptotically to zero within a short period — probably a few revolutions.

Mathematical Model

Considering the spacecraft as an undamped, spinning, symmetrical, rigid body with constant spin speed ω_z and a spin axis moment of inertia greater than the transverse moment of inertia, $I_z > I_x = I_y$, then the Euler equations of motion (in body coordinates x, y, z) resulting from synchronous axial jet pulsing may be represented in complex form by ($\dot{\omega} = \frac{d}{dt}\,\omega$)

$$\dot{\omega} + j\,\Omega\,\omega \approx n; \; j = \sqrt{-1} \tag{3-1}$$

$$\Omega = \left(1 - \frac{I_z}{I_x}\right)\omega_z \equiv \omega_z - \omega_n \equiv \left(1 - \frac{I_z}{I_x}\right)\frac{2\pi}{\tau_s} < 0 \tag{3-2}$$

$$n = \left\{ \begin{array}{ll} n_o = \dfrac{No}{I_x} & ; q\,(m+k)\;\tau_s \le t \le \left[q\,(m+k) + k\right]\,\tau_s \\ \\ 0 & ; \left[q\,(m+k)+k\right]\tau_s \le t \le (q+1)\,(m+k)\,\tau_s \end{array} \right\}; \tag{3-3}$$

$$q = 0,\ 1,\ 2,\ \ldots,\ \nu - 1$$

where

$\omega = \omega_k + j\,\omega_y$

$=$ component of body angular velocity normal to spin axis, rad/sec

τ_s = spin period, seconds

$= 2\pi/\omega_z \le 0.8$ second (75 rpm)

ω_n = nutation frequency, rad/sec

$= \dfrac{I_z}{I_x}\,\omega_z$

n = normalized torque, ft-lb/slug-ft^2

$= N/I_x = \dfrac{1}{I_x}\,(N_x + jN_y)$

k = fraction or number of jet-on spin periods per on-off cycle

> 0

m = fraction or number of jet-off spin periods per on-off cycle

≥ 0

$$\frac{k}{m + k} = \text{duty cycle of axial jet}$$

q = running index of on-off cycles

$= 0, 1, 2, \ldots, \nu - 1$

ν = total number of on-off cycles in a pulse series

For synchronous pulse torquing at the rate of one pulse per spin period

$$0 < k < 1$$

$$m + k = 1 \tag{3-4}$$

and ν, the total number of pulses, is completed in $\tau \cong (\nu - m)\,\tau_s$ second. For the continuous operating mode, however, the thrust history of the axial jet is described by a single, long duration pulse of many spin periods, i. e.,

$$k >> 1$$

$$m = 0 \tag{3-5}$$

and the action time of the axial jet $\tau_a = k\,\tau_s$ seconds.

A solution to Equation 3-1 for ω is given by

$$\omega = \omega_o e^{-j\Omega\tau} + \frac{2n}{\Omega}\;\frac{\sin\left(\frac{\Omega}{2}k\tau_s\right)\sin\left[\frac{\Omega}{2}\;\nu(m+k)\tau_s\right]}{\sin\left[\frac{\Omega}{2}(m + k)\;\tau_s\right]}\;e^{-j\,\frac{\Omega}{2}\left[\nu(m+k) - m\right]\tau_s} \tag{3-6}$$

where

τ = total time for completion of pulse series

$= \left[\nu\,(m + k) - m\right]\tau_s$

ω_o = initial component of body angular velocity normal to spin axis (assumed zero)

Now, since the subsequent nutation angle θ is given by

$$\tan\theta = \frac{\omega}{\omega_n} = \frac{\omega}{\omega_z}\,\frac{I_x}{I_z} \approx \theta \tag{3-7}$$

then from Equations 3-2 and 3-6

$$\tan\theta \approx \theta = \frac{\omega_o}{\omega_n} e^{-j\Omega\tau} + \frac{2N \sin\left[\pi k\left(1 - \frac{I_z}{I_x}\right)\right] \sin\left[\pi \nu (m+k)\left(1 - \frac{I_z}{I_x}\right)\right]}{\omega_z^2 I_z \left(1 - \frac{I_z}{I_x}\right) \sin\left[\pi (m+k)\left(1 - \frac{I_z}{I_x}\right)\right]}$$

$$\exp\left\{-j\frac{\Omega}{2}\left[\nu(m+k) - m\right]\tau_s\right\} \tag{3-8}$$

<u>Pulsed Mode</u>

For the case of one pulse per spin cycle ($m + k = 1$) and $\omega_o = 0$, Equation 3-8 becomes

$$\theta \approx \frac{2N \sin\left[\pi k\left(1 - \frac{I_z}{I_x}\right)\right] \sin\left[\pi \nu\left(1 - \frac{I_z}{I_x}\right)\right]}{\omega_z^2 I_z \left(1 - \frac{I_z}{I_x}\right) \sin\left[\pi\left(1 - \frac{I_z}{I_x}\right)\right]} e^{-j\frac{\Omega}{2}(\nu - m)\tau_s} \tag{3-9}$$

The above expression may be further reduced by examining the magnitude of $\sin\left(\frac{\Omega}{2} k\tau_s\right) = \sin\left[\pi k\left(1 - \frac{I_z}{I_x}\right)\right]$.

Recall that

$$\frac{\Omega}{2} k\tau_s = \frac{\omega_z}{2}\left(1 - \frac{I_z}{I_x}\right) k\tau_s = \pi k\left(1 - \frac{I_z}{I_x}\right)$$

For a 45-degree pulse width $k = 1/8$, and since $\left|\left(1 - \frac{I_z}{I_x}\right)\right| \leq 0.3$

$$\left|\frac{\Omega}{2} k\tau_s\right| \leq \frac{\pi}{8}(0.3) = 0.118 \text{ radian}$$

$$= 6.75 \text{ degrees}$$

Thus

$$\sin\left(\frac{\Omega}{2} k\tau_s\right) \approx \frac{\Omega}{2} k\tau_s \cong \frac{\Omega}{2}\frac{\delta H}{N} = \frac{\omega_z}{2}\frac{\delta H}{N}\left(1 - \frac{I_z}{I_x}\right) \tag{3-10}$$

where δH is the incremental change in the direction of the angular momentum vector $H \cong I_z \omega_z$. Hence (neglecting the phase angle) Equation 3-9 becomes

$$\frac{|\theta|}{\delta H/H} \approx \left| \frac{\sin\left[\pi \nu \left(1 - \frac{I_z}{I_x}\right)\right]}{\sin\left[\pi \left(1 - \frac{I_z}{I_x}\right)\right]} \right| \tag{3-11}$$

When, in Equation 3-11

$$\nu = \frac{1 - 2r}{2\left(1 - \frac{I_z}{I_x}\right)} \quad ; \quad r = 1, 2, 3, \ldots\ldots \; ; \tag{3-12}$$

$$|\theta| = |\theta|_{max} = \frac{\delta H}{H} \left| \frac{1}{\sin\left[\pi\left(1 - \frac{I_z}{I_x}\right)\right]} \right| = \frac{\pi N}{4 I_z \omega_z^2} \; \frac{1}{\sin\left[\pi\left(\frac{I_z}{I_x} - 1\right)\right]} \tag{3-13}$$

where k = 1/8. Some values of θ_{max} for N = 10 ft-lb and k = 1/8 are given in Table 3-1 for typical and worst case moment of inertia ratios and spin speeds with I_z = 56.75 slug-ft^2.

TABLE 3-1. MAXIMUM NUTATION ANGLE AFTER PULSED MODE

$\frac{I_z}{I_x}$	ω_z, rpm	θ_{max}, degrees
1.1	75	0.42
1.2	75	0.217
1.1	100	0.238
1.2	100	0.112

Continuous Mode

For a single, long duration pulse, $m = 0$, $\nu = 1$, $\tau = \tau_a = k\tau_s$, so that Equations 3-6 and 3-7 reduce to

$$\theta \cong \frac{\omega_o}{\omega_n} e^{-j\Omega\tau_a} + \frac{2n}{\Omega\omega_n} \sin\left(\frac{\Omega}{2}\tau_a\right) e^{-j\frac{\Omega}{2}\tau_a} \qquad (3\text{-}14)$$

Since $\tau_a = k\tau_s >> \tau_s$ the small angle approximation for $\Omega k \tau_s/2$ can no longer be invoked. For example, if $I_z/I_x = 1.2$

$$\frac{\Omega k \tau_s}{2} = \pi k \left(1 - \frac{I_z}{I_x}\right) = \frac{\pi}{2} \qquad (3\text{-}15)$$

when

$$k = \frac{2r - 1}{2\left(\frac{I_z}{I_x} - 1\right)} \quad ; \quad r = 0, 1, 2, \ldots$$

$$\approx \frac{1}{0.4} = 2.5 \quad ; \quad r = 0 \qquad (3\text{-}16)$$

Thus for $\omega_o = 0$ in Equation 3-14 the expression for $|\theta|_{max}$ is approximated by

$$|\theta|_{max} = \frac{2n}{\Omega\omega_n} = \frac{2N}{I_z\omega_z^2\left(\frac{I_z}{I_x} - 1\right)} \qquad (3\text{-}17)$$

The ratio of Equation 3-17 to Equation 3-13 shows

$$\frac{|\theta_{max}| \text{ continuous}}{|\theta_{max}| \text{ pulsed}} = 8 \frac{\sin\left[\pi\left(\frac{I_z}{I_x} - 1\right)\right]}{\pi\left(\frac{I_z}{I_x} - 1\right)} \begin{matrix} \geq 6.9 \\ \leq 8 \end{matrix}$$

for $1 < I_z/I_x \leq 1.3$. Thus, it is seen that the worst case hot gas jet induced nutation angle occurs after continuous mode operation of the axial jet.

Table 3-2 contains some values of the maximum nutation angle θ_{max}, induced by the axial jet operated in the continuous mode. These values are listed for various combinations of spin speed ω_z, and roll-to-pitch moment of inertias I_z/I_x, with the additional conservative assumptions that the torque N = 10 ft-lb and I_z = 56.75 slug-ft^2 (minimum value).

TABLE 3-2. MAXIMUM INDUCED NUTATION ANGLE (θ_{max})*

ω_z, rpm	$\frac{I_z}{I_x}$	θ_{max}, degrees	N, ft-lb	I_z, slug-ft^2
75	1.10	3.25 (2.11)**	10 (6.5)**	56.75
75	1.13	2.50 (1.63)	10 (6.5)	56.75
100	1.10	1.82 (1.18	10 (6.5)	56.75
75	1.22	1.48	10	56.75
100	1.13	1.40 (0.91)	10 (6.5)	56.75
75	1.30	1.09	10	56.75
100	1.22	0.83	10	56.75
100	1.30	0.61	10	56.75

*Continuous mode operation of axial jet for over 2-1/2 spin periods.

**Parenthetical values correspond to final blow-down thrust level of approximately 3 pounds.

4. SPACECRAFT SYSTEMS DESIGN

GENERAL STATUS REPORT

All transponder units are either in fabrication or unit test. In-process test plans are being generated to assure that a complete set of engineering data is obtained. A breadboard of the command decoder has been built and tested. No errors in logic were discerned during the tests which demonstrated both the frequency shift keying and count mode of operation.

Initial procurement of both battery cells and solar cells is underway with delivery scheduled for mid-October.

Alternate structural design studies are continuing with emphasis on improved roll-to-pitch ratio. Location of all control items has been designated and required interconnections specified. Two fuel depletion firings of the bipropellant reaction control system occurred during this month, demonstrating durability of the engineering model unit.

COMMUNICATION TRANSPONDERS – GENERAL STATUS

The current block diagram for the transponders is shown in Figure 4-1. With the elimination of the requirement for a beacon in the multiple-access mode, the receiver ferrite switch can be deleted and replaced by a simple tee. This change reduces weight and simplifies the transponder regulators since the ferrite driving circuit can be removed. The receiver ferrite switch will be included in the present engineering model to avoid last-minute circuitry changes.

The ferrite switch in the output transmitter may be replaced by an Electronics Specialty Company relay. This relay is being redesigned to have OSM connectors. Advantages of this system will be: 1) a weight of 2.5 ounces compared to 4.5 ounces for the ferrite switch; 2) RF properties are comparable and 3) switching current is 600 milliamperes for the relav as compared to ampere for the ferrite switch. This might allow simplification of the power supply regulator. Dimensions of the relay are considerably less than the ferrite switch.

Transponder Fabrication

Fabrication of the transponder structures has been completed. Assembly of the dual-mode transponder is approximately 20 percent complete. Coaxial cabling locations have been established; microwave units have been completed and assembled to the structure.

Transponder Components Status

Multiple-Access Transponder Components

Multiple-Access Preamplifiers. The first of the two units for the transponders have been fabricated, tested,and the bonding process completed.

Filter Amplifiers. Both of the two required units are undergoing final adjustments. When this is completed, both will be ready for installation.

Phase Modulators. Both units have satisfactorily undergone checkout testing and are now being bonded.

Doubler Amplifiers. The first of the two units for the transponders has been bonded, and following final adjustments will be ready for installation. The second unit has been fabricated, but will require some minor rework following its initial test. This unit is now undergoing checkout testing.

Master Oscillator Amplifiers. The first of the two units will be available for installation as soon as final adjustments are completed. The second unit is now undergoing checkout testing.

Crystal Master Oscillators. The first of the two required units will be available for installation immediately following completion of final adjustments. The second unit is now undergoing checkout testing.

Frequency-Translation Transponder Components

Preamplifiers. Both units have been fabricated and are now undergoing checkout testing.

Intermediate Amplifiers. Both transponder units have been fabricated. Checkout testing for the first has been completed and will undergo the bonding process. The second unit required minor rework and is being prepared for checkout testing.

The following transponder units have been fabricated and are now undergoing checkout testing:

Postamplifiers

Crystal master oscillators

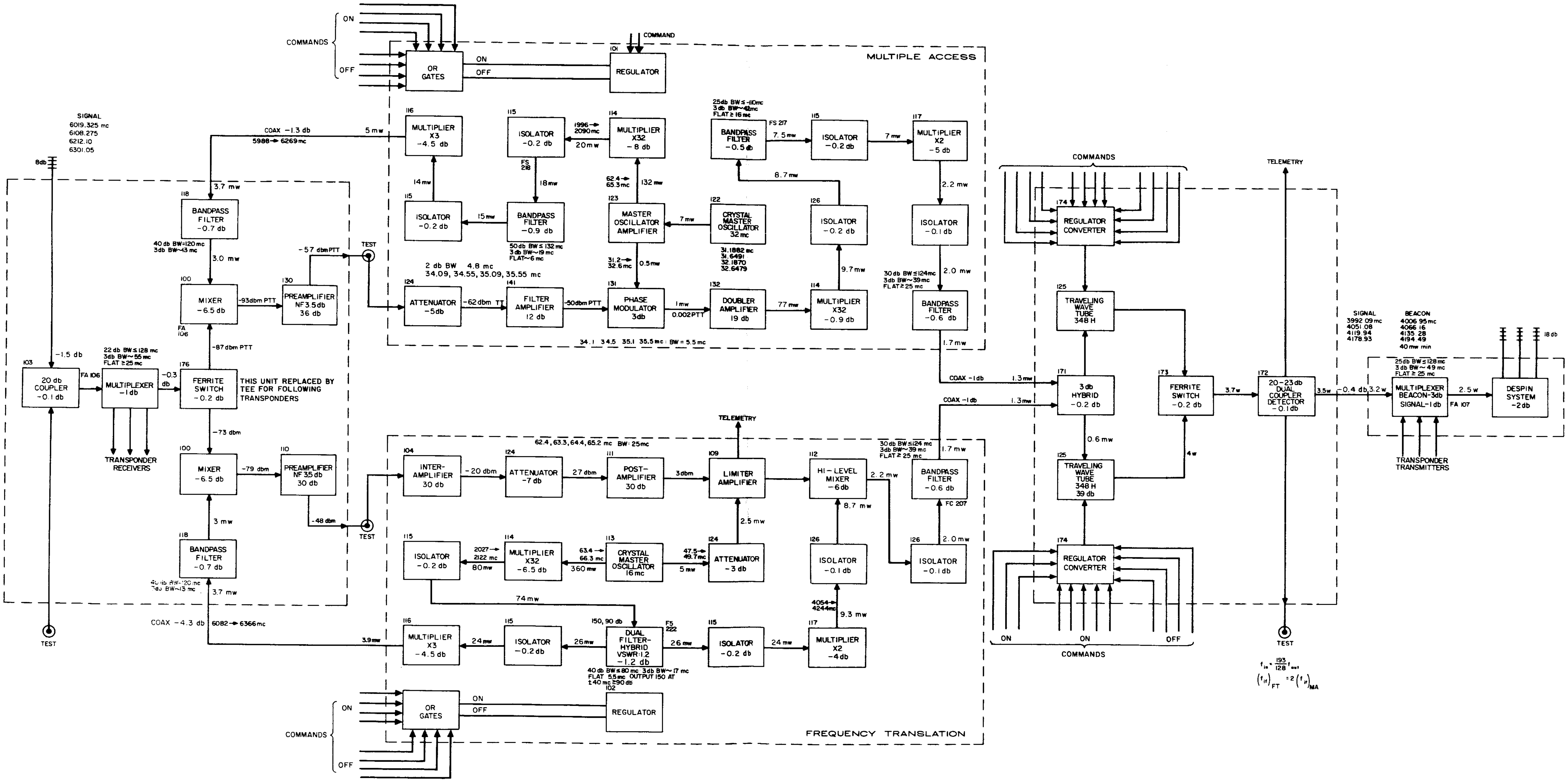


Figure 4-1. Advanced Syncom Transponder

Limiter amplifiers

High level mixers

Multiple-Access and Frequency-Translation Transponder Units

Attenuators. Parts for all six units are available. These units will be assembled as required.

X32 Multipliers. All four units are now complete and are available for installation. Test set units are also available.

Input and Output Multiplexers. Checkout testing is awaiting vendor delivery of these items.

Bandpass Filters. The required four units are now complete and are ready for installation.

Isolators (115). Fifteen of these units have been completed and are available for installation.

Isolators (126). All six units have been completed and are available for installation.

Transmitter RF Switch. Fabrication has been completed on both required units. When checkout testing is completed, these units will be ready for installation.

Input Mixer. All four of the required units have been completed and are available for installation.

Dual Filter Hybrid. These units have been received from Rantec. After final adjustment they will be ready for installation.

Directional Coupler. Two units have been completed and are now ready for installation.

3-db Hybrid. Both of the required units are awaiting final inspection prior to installation.

Dual Coupler Detector. Fabrication of the two required units is awaiting purchased power-monitoring diodes. Their fabrication is approximately 75 percent complete.

Specification Status of Major Control Items and Selected Combinations

Specifications are in process for the following items, including combinations of minor control items that are to be tested together prior to test of the transponders:

1) Dual mode transponders

2) Master oscillator, master-oscillator amplifier, X32 multiplier, and isolator

3) Multiple-access combination of master oscillator, master-oscillator amplifier, phase modulator, doubler amplifier, X32 multiplier, and isolator

4) Multiple-access combination of master oscillator, master-oscillator amplifier, X32 multiplier, isolator, bandpass filter, isolator, X3 multiplier and bandpass filter

5) Frequency-translation combination of master oscillator, X32 multiplier, and isolator

6) Frequency-translation combination of master oscillator, attenuator, limiter amplifier, high-level mixer, isolator, and bandpass filter

Specification Status — Minor Control Items

In-process test specifications have been written in draft form for 28 of the 31 transponder and transmitter minor control items required. These specifications are being used as a basis for checkout of the hardware now undergoing tests.

Transponder Regulators

The first set of transponder regulators (101 and 102 units) have been fabricated and are undergoing initial tests. Certain minor changes will be incorporated to ensure dynamic stability of the high-gain feedback loops. The units will then be subjected to extensive environmental testing.

The ON/OFF "OR" gates will be located at the quadrant plug input, thus reducing the number of feed-through capacitors required. Changes are anticipated for the final 101 and 102 regulator configuration (not to be installed in the present hardware).

1) ON/OFF drivers — The present hardware was fabricated with dc-coupled ON/OFF drivers; however, an ac-coupled system will be used.

2) Ferrite switch drive — It is anticipated that the ferrite switch will be removed at the input to the transponder. This will eliminate the need for the ferrite switch drive circuitry now in the regulator. In addition, the Darlington output stage and the overcurrent trip disable circuitry will no longer be required when the ferrite switch drive is removed.

A load analysis for the transponder regulators follows:

Multiple-Access Transponder Receiver	Current, Milliamperes
130 Preamplifier	3.58
141 Filter amplifier	2.8
122 Master oscillator	3.65
123 Master oscillator amplifier	33.6
131 Phase modulator	28.0
132 Doubler amplifier	32.5
114 X32 multiplier (2)	22.0
	$126.13 \approx 126$

Frequency-Translation Transponder Receiver	Current, Milliamperes
110 Preamplifier	7.34
104 Interamplifier	7.34
111 Postamplifier (less zener current)	8.8
109 Limiter amplifier	28.0
113 Master oscillator	47.7
114 X32 multiplier	11.0
	$110.18 \approx 110$

The hardware currently being fabricated will have the new ac-coupled filament ON/high voltage ON/traveling-wave tube OFF drivers. The output diodes and filter components have been selected for the high-voltage dc-dc converter. It is necessary to use 1000-volt capacitors in the Helix-collector and collector-cathode outputs, and 600-volt capacitors in the anode-Helix output. Because of the size and weight of high voltage capacitors, it was considered desirable to place more of the filter weight in chokes than was done in Syncom I.

The traveling-wave tube will require ±1 percent voltage regulation on the Helix-cathode output and ±2 percent regulation on the other high voltage outputs, for unregulated bus variations, temperature changes, and component tolerances. Load regulation is not of significance because the traveling-wave tube load is quite constant during normal operation. When the RF signal is removed the traveling-wave tube load changes, but specification performance is not required. Line regulation is approximately 0.05 percent total deviation for unregulated bus voltage variations of -31 ±5 volts. Component tolerances will be cancelled out by adjusting the series regulator to give the correct Helix-cathode full load voltage, rather than striving for -24 volts converter input voltage. The major problem will be that of temperature regulation. It will be necessary to replace the Syncom I type of voltage reference and sensing circuit with the temperature compensated type currently installed in the Advanced Syncom 101 unit (transponder multiple-access mode regulator). The 101 unit is discussed in detail on page 4-44 and in Table 4-14 of the June 1963 status report. Syncom I experience indicates that the high-voltage converter output should vary no more than 0.2 percent total deviation because of the anticipated temperature changes. The series regulator may contribute an additional 0.2 percent temperature regulation, yielding a total of 0.4 percent of the allowable 2 percent (±1 percent) deviation.

Regulators (Command 212 Unit, Telemetry 222 Unit)

The command regulator (212 unit) has not been fabricated yet; however, no technical difficulties are anticipated. The first telemetry regulator (222 unit) has been fabricated, but not tested. The following changes are contemplated for the 222 unit:

1) Replace the present telemetry bias supply with a larger dc-dc converter having multiple outputs to supply the present bias load plus the telemetry encoder bias power requirements.

2) The dc-coupled ON/OFF drivers will be replaced by the new ac-coupled networks. At that time the "OR" gate diodes will be installed.

TRAVELING–WAVE TUBE POWER AMPLIFIER

Several trouble areas were resolved during the report period. The magnitude of the output power variation has been greatly reduced by the pre-aging stage of production. The high degree of cathode voltage regulation necessary for the traveling-wave tube to maintain the performance specifications has been partially eliminated. A meaningful test program for the ten life test tubes was also outlined.

The effects of the output power variations of the traveling-wave tube (caused by a charging phenomenon) on the communication system were investigated. It was concluded that the magnitude of this variation would not affect the communications. The addition of the preaging and refocusing production stages has reduced the magnitude of this variation so that it is no longer considered a threat to the yield rate of flight quality tubes. However, to learn the nature of this phenomenon, four experimental tubes have been constructed and are awaiting test.

Figure 4-2 shows the output power of a typical tube as a function of frequency and RF input power for constant operating voltages. The points of high and low overall efficiency (including heater power) are also indicated. The line of maximum power (saturated) transverses the surface from about the line ($f = 3.95$ gc, and $P_{in} = 0.4$ milliwatt) to the line ($f = 4.20$ gc and $P_{in} = 0.7$ milliwatt. To meet the minimum output power (4.0 watts) at $f = 3.95$ gc, $P_{in} = 0.7$ milliwatt and $f = 4.20$ gc, $P_{in} = 0.4$ milliwatt, it is necessary to have the saturated power between 4.4 to 4.7 watts.

Figure 4-3 shows the effect of ±1 percent cathode voltage regulation on the output power surface. As illustrated, the output power drops below the required value at certain points. Greater permissible voltage regulation over this range of input power and frequency can only be obtained at the expense of more total dc power input. This problem was discussed with the following groups: communication system design, transponder design, and traveling-wave tube power supply. A tentative decision was reached to supply two tube assembly numbers. One tube would be used for the lower frequency channels and beacons, the other for the higher frequency channels and beacons. However, one basic tube will still be used. It will be tuned for the two assembly numbers at the time of testing. The power supply will also maintain ±1 percent voltage regulation of the specified cathode voltage. All other voltage regulations will still be at ±2 percent. In this manner, the required output power can be obtained without an efficiency drop.

In the present program, 10 tubes will be selected for life testing. These tubes will be selected after they have undergone preliminary environmental (vibration, high vacuum, cold test) testing. The tubes will be sorted into three test groups. The length of test time will be a minimum of 1 year.

Group	Number of Tubes	Test
1	6	Continuous operation at laboratory ambient conditions.
2	2	Same as Group 1, except with the anode and collector voltage at zero. Helix voltage will be adjusted to obtain same total current.
3	2	Same as Group 2 except the collector voltage will be adjusted to give normal helix current.

The Group 1 test simulates the normal operation and will be the reference test from which the other tests can be compared. It will also provide important mean-time-between-failure data for normal operation. The Group 2 test will determine the effectiveness of present ion trapping ($V_a > 0$) on life. The Group 3 test will be an acceleration version of Group 2. It will provide information on the contribution of Helix current to total ion content.

Fabrication Status

Standard tube production had been stopped for 3 weeks because of the charging problem; however, tube production has been resumed at a faster rate. The production status at the end of this report period is:

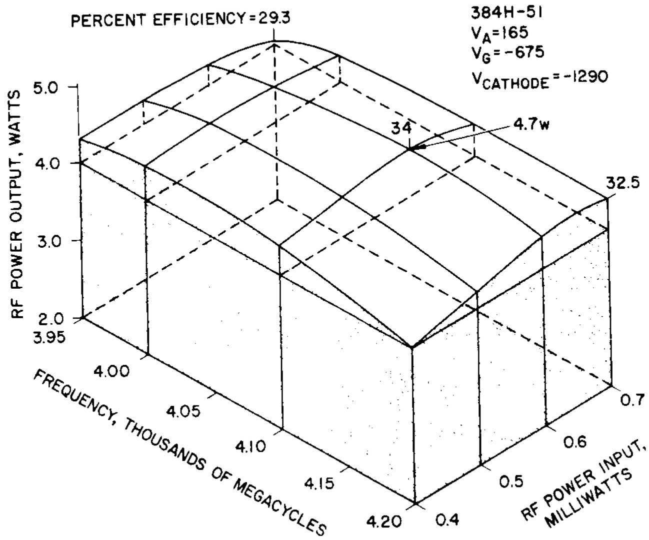
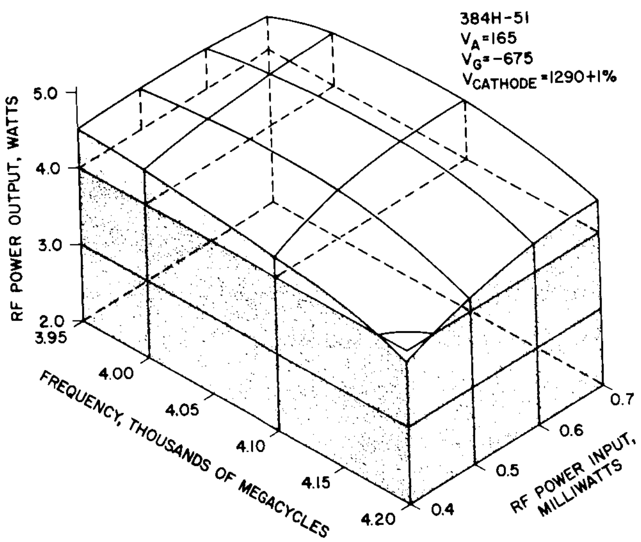
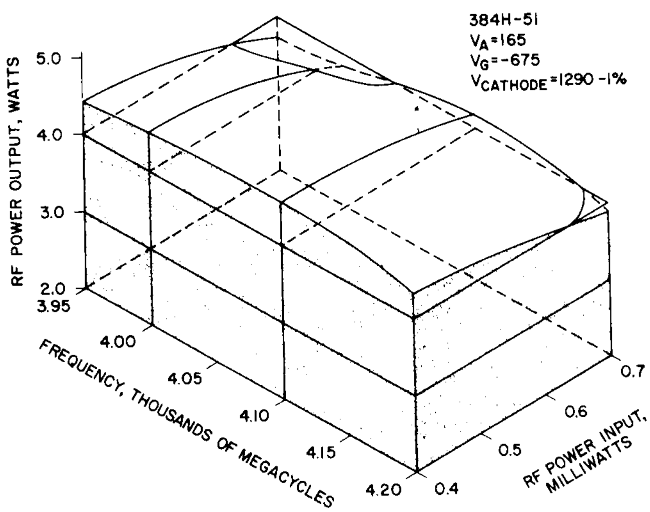


Figure 4-2. Output Power of a Typical Tube as a Function of Frequency and RF Input for Constant Operations Voltages



a) +1 Percent Cathode Voltage



b) -1 Percent Cathode Voltage

Figure 4-3. Effect of Voltage Regulation on the Output Power Surface

Stage	Description	Tube
I	Clean room assembly	4
II	Bake-out process	2
III	Magnet assembly	—
IV	Focusing and RF testing	—
V	Preaging	2
VI	Refocusing and RF testing	2
VII	Packaging	—
VIII	RF testing after packaging	1
IX	Environment testing	6
X	Shipped	2

Life Improvement Program

The results of the composition analysis of the cathode after wet hydrogen firing in the new composition tube have not yet been received.

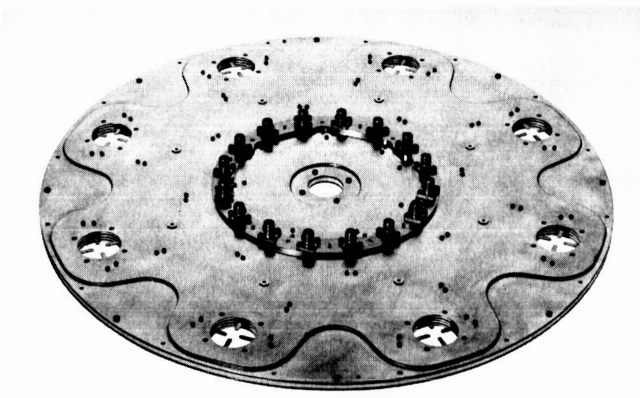
The first diode has been tested for temperature correction factors. These results will appear in the Summary Report. The cathode temperature for normal heater voltage was determined to be about 705° ±5°C. The diode test rack and power supplies will be completed by 18 October 1963.

PHASED ARRAY TRANSMITTING ANTENNA

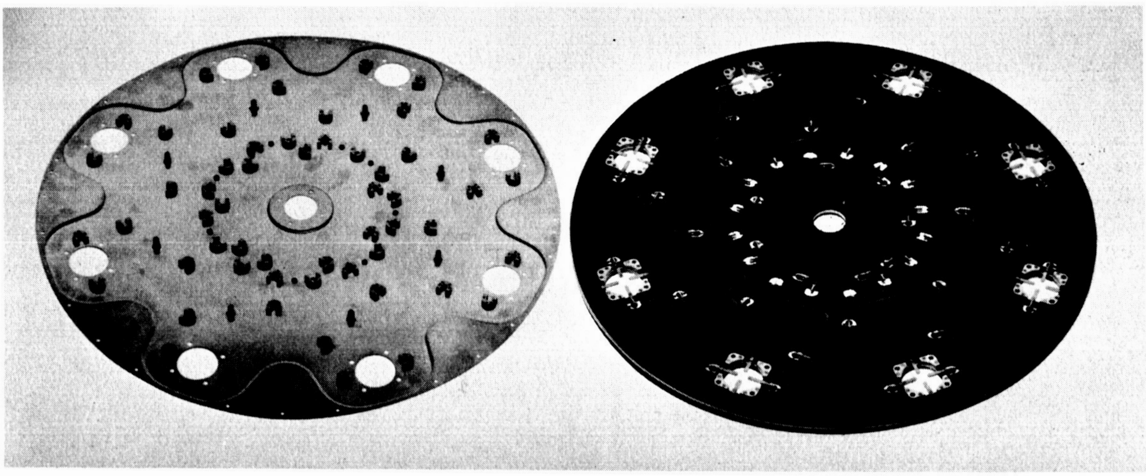
All of the stripline circuits and ferrite sections have been assembled. The phased array assembly is complete and is ready for electrical test. All parts of the multilayer output coupler fitted integrally according to design.

A series of photos showing the various layers of the output coupler are shown in Figure 4-4. In each succeeding figure, the top layer on the right has been lifted off, turned over, and placed on the left. The horseshoe-shaped pieces on the ground planes are used for matching the vertical transitions between stripline. Close-up views of the 90-degree hybrid and the four probe coupler are shown in Figure 4-5. A similar photo of the power splitter unit is shown in Figure 4-6. The close-ups in Figure 4-7 show how the two orthogonal probes are terminated in resistive loads.

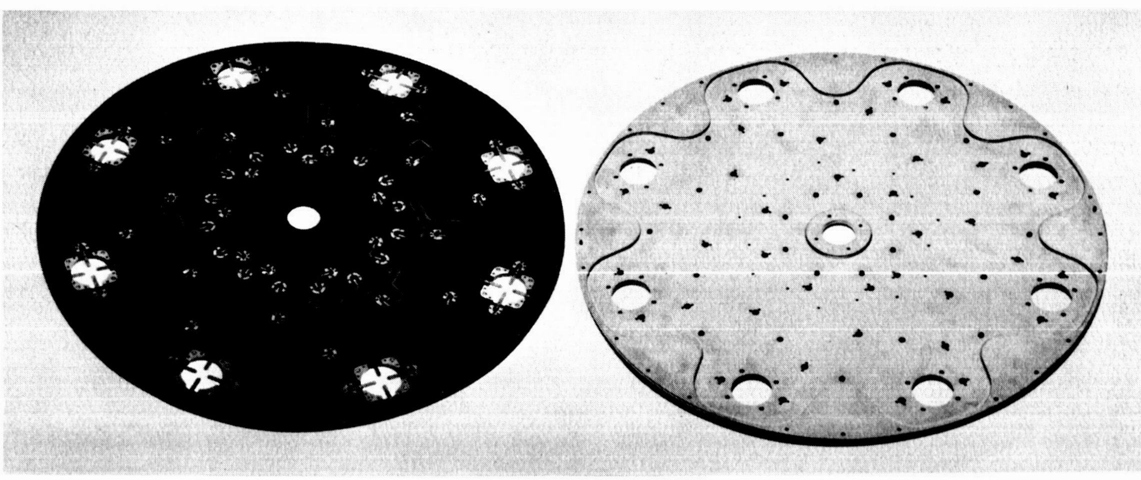
The ferrite phase shifter sections are fabricated separately. The field winding slides over an aluminum tube to which flanges are attached at



a) Top View Output Coupler

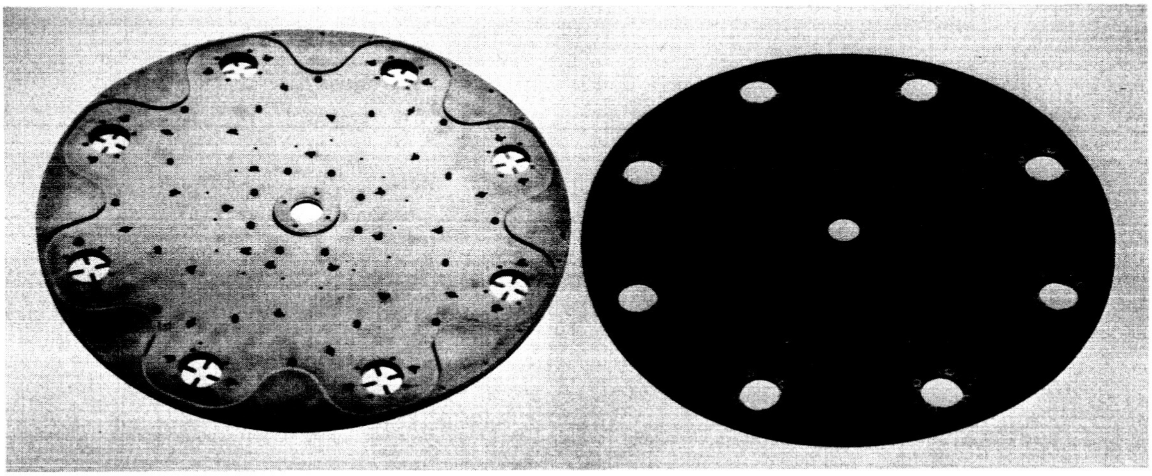


b) Top Ground Plane, Top Circuit Board

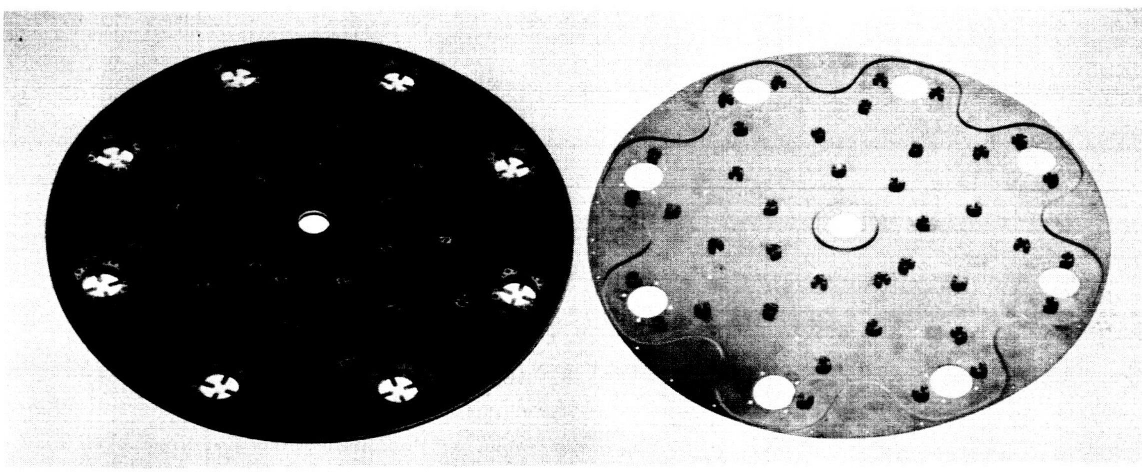


c) Top Circuit Board, Center Ground Plane

Figure 4-4. Assembly Views of Output Coupler

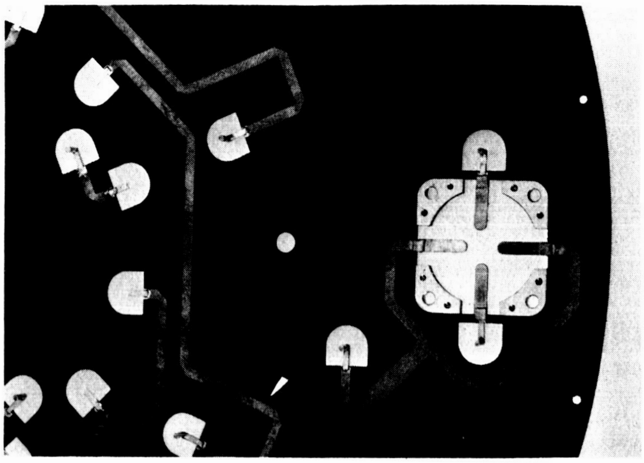


d) Center Ground Plane, Bottom Circuit Board

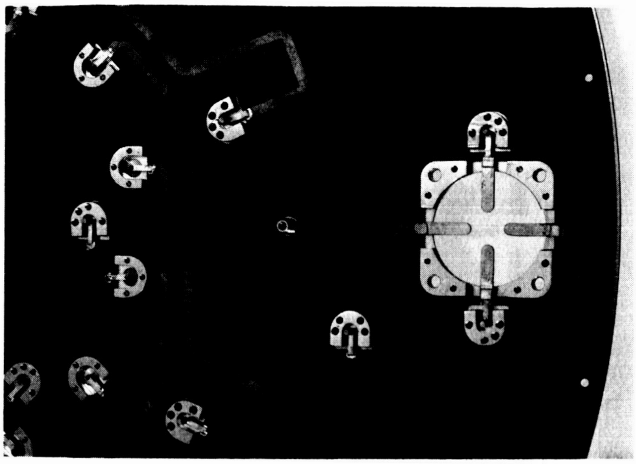


e) Bottom Circuit Board, Bottom Ground Plane

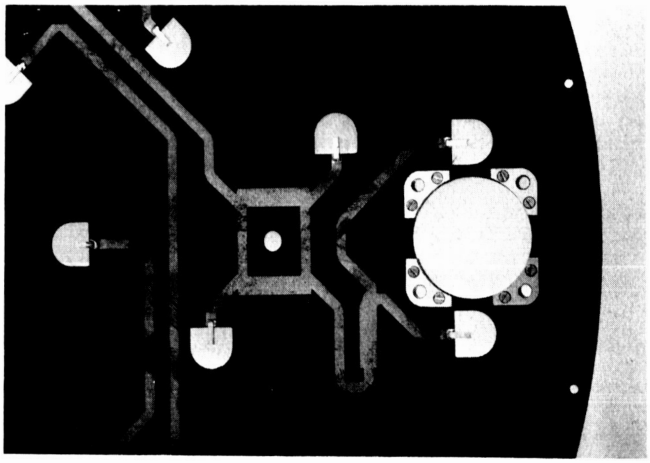
Figure 4-4 (continued). Assembly Views of Output Coupler



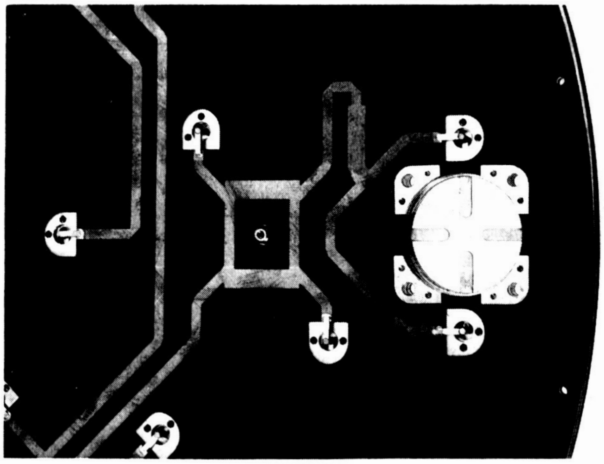
a) Top Circuit Board



b) Top Circuit Board on Top Ground Plane



c) Bottom Circuit Board Showing Hybrid



d) Bottom Circuit Board Connected to Top Board Through Center Ground Plane

Figure 4-5. Closeups of Output Coupler Stripline

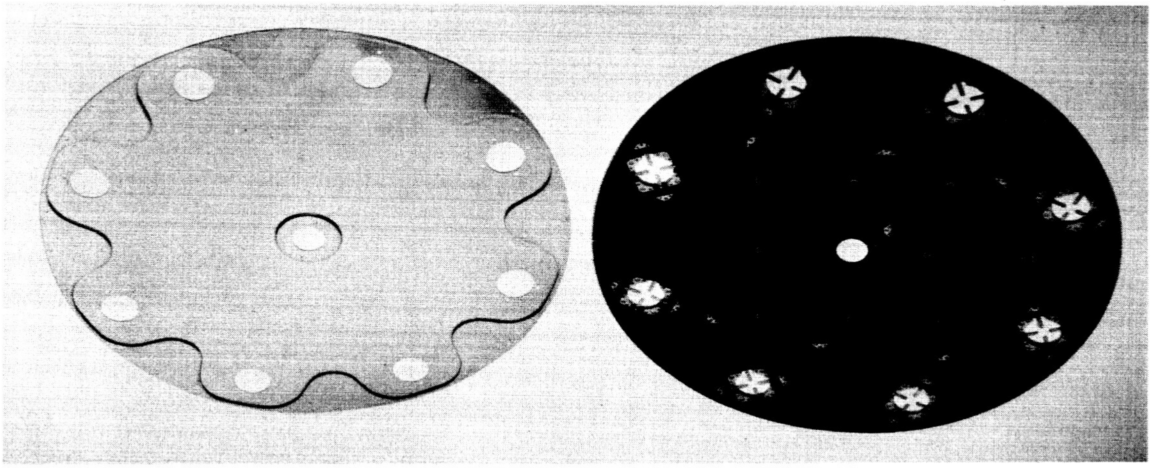


Figure 4-6. Power Splitter Stripline and Ground Plane

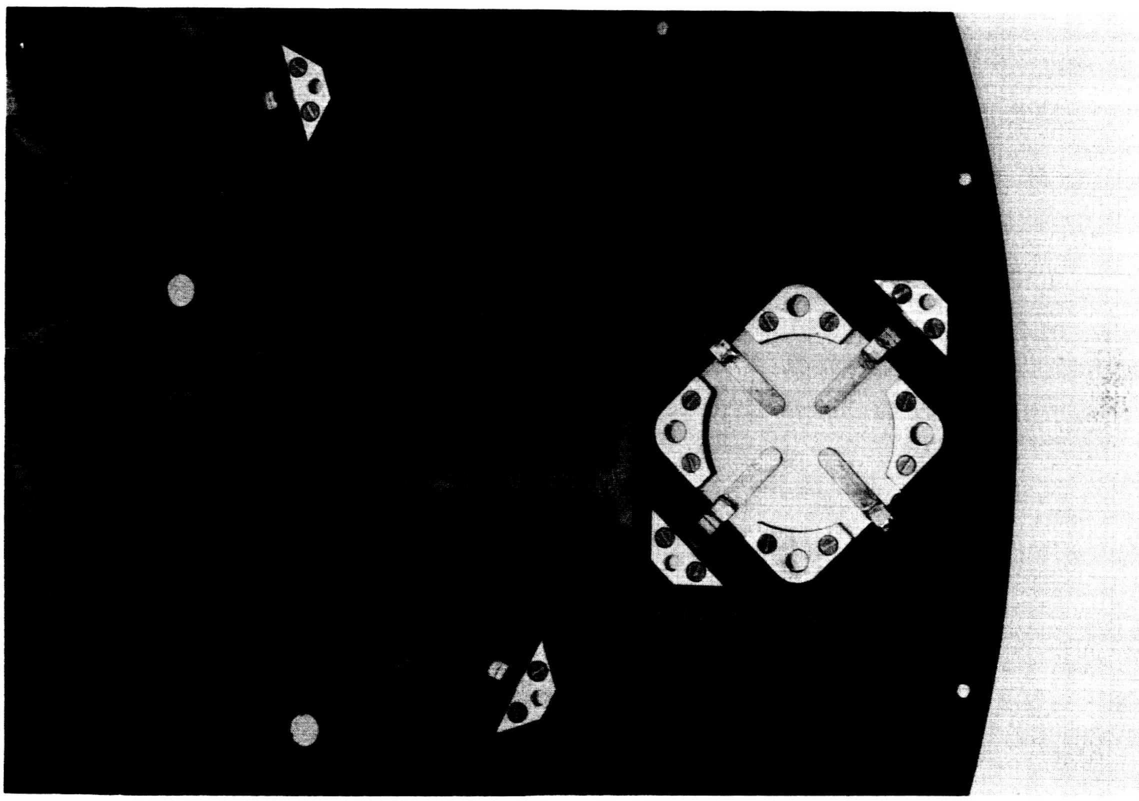


Figure 4-7. Power Splitter Input Probe Coupler Showing Resistance Terminations

each end. These flanges are fastened to the power splitter and output coupler. Figure 4-8 shows the completely assembled stripline, and Figure 4-9 illustrates the complete array.

PHASED ARRAY CONTROL ELECTRONICS (PACE)

Advanced Engineering Model

Checkout of the advanced engineering model (AEM) is complete and it is being used to test design improvements for some of the circuits. Since life testing was begun on 28 August 1963, the AEM version of the PACE (flat circuit cards) has been intermittently operated for approximately 530 hours, excluding checkout and environmental testing time. The steady-state error of the frequency lock loop is being recorded daily with no significant change noted. The waveform generator and digital readout encoder redundancy were also checked out during this period.

On 20 September 1963, the AEM was integrated with the phased array antenna; however, excessive sidelobes existed in the antenna pattern. Subsequent check of the PACE indicated that two carbon film resistors in one of the auxiliary voltage supplies had drifted well out of specification, causing degradation of output waveform quality. The resistor change was probably caused by operation over the wide temperature range of -50 to +125°C during previous environmental evaluation. The resistors were of a carbon film type readily available in in-house electronic stores; the IRC XLT metal film resistor will be used in the spacecraft. The AEM will shortly be reintegrated with the antenna.

The low voltage version of the phase shifter driver unit for the AEM has completed product design and is in fabrication. Component ordering is 75 percent complete.

Advanced Development Model (ADM)

Product Design Status

Prerelease of module assembly drawings to fabrication was completed during the month of September. Function block encapsulation tooling drawings were also prereleased to fabrication during September. Taping and photography of all etched circuit boards have been completed, and the assembly drawings have been prereleased. All components required to fabricate the advanced development model (ADM) have been delivered to fabrication.

Changes are taking place in the flight unit design which will not be reflected in the ADM because of differences in vibration levels and stress analysis. As many of these changes as possible, however, will be incorporated in the ADM without affecting the schedule.

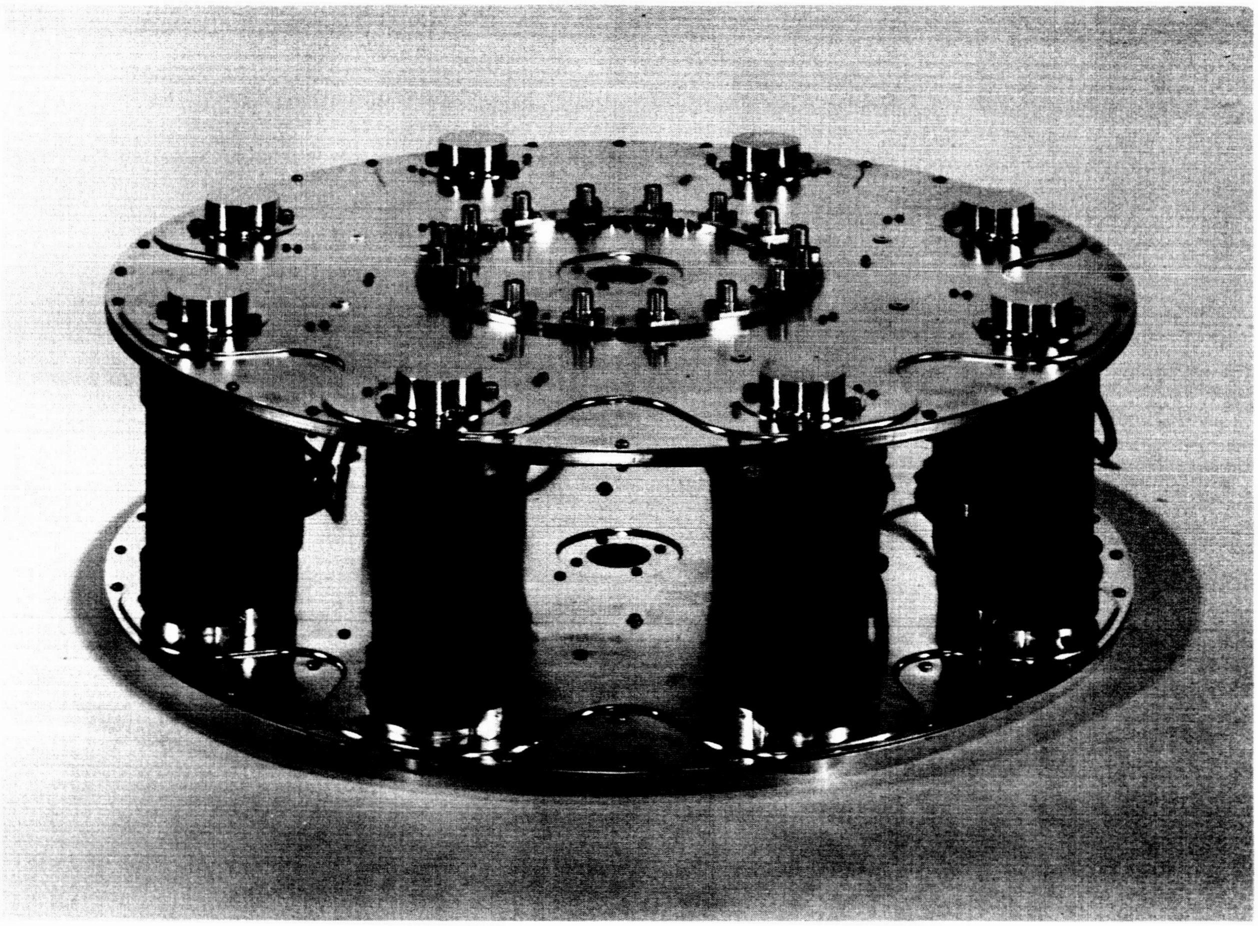


Figure 4-8. Assembled Stripline Circuits and Phase Shifter

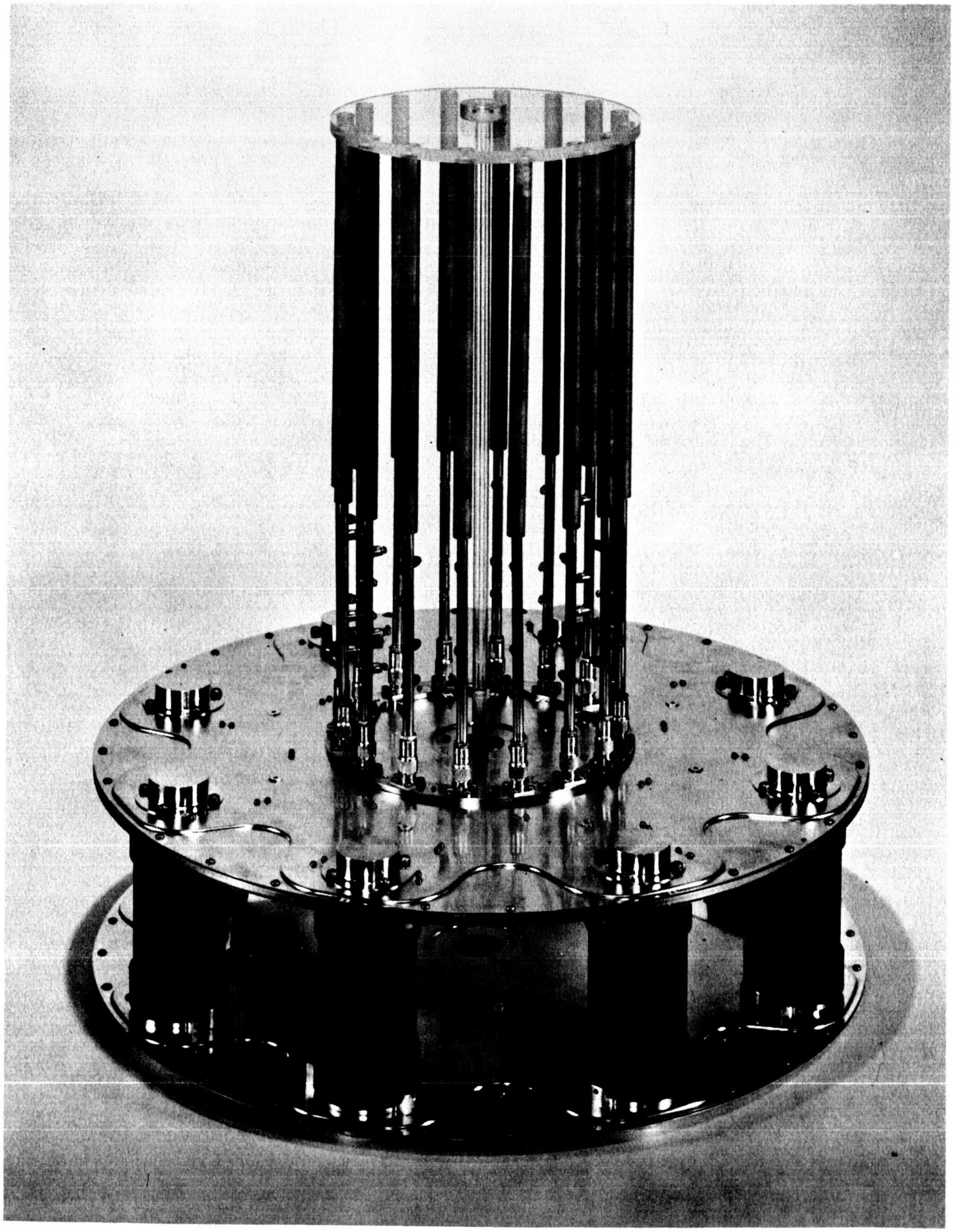


Figure 4-9. Completely Assembled Phased Array

Test Equipment Status

PACE and JCE Module Tester. This tester is essentially complete. The Hughes-fabricated portion has been completed and the console and all special test equipment received. The equipment will be mounted in the console as soon as maintenance installs the 60-cycle power outlets. In the meantime, the equipment is grouped together on a work bench and is being used to test welded modules as they arrive from fabrication. Test procedures have been written for all of the basic PACE modules.

PACE Unit Tester. The logic, circuit, and packaging designs are complete. Fabrication is complete except for the adapters which will be needed to connect to the function boards during testing.

Fabrication and Checkout Status

Welded Modules. Tests of all PACE ADM components are now complete. Greatest attrition occurred in tantalum capacitors and molded deposited carbon film resistors. Since these were standard grade commercial components, the failures were within the expected levels. Four each of the 473600 (standard T flip-flop) and the 473608 (digital readout encoder) modules have been fabricated and tested. Six of the modules passed on the first test; one module passed after two transistors and one diode were replaced, and the remaining module has had a transistor removed for evaluation. Nine additional modules are in fabrication. The remaining 39 will be started as component holders are completed. Almost all components are on hand.

Function Blocks. Fabrication of the four etched boards for the ADM function blocks has been started and will be completed by early October. The units for the ADM and the dummy units to be vibrated with other quadrant electronics are presently in fabrication.

PACE Circuit Development

Careful review of the PACE and psi-2 angle counter advanced engineering model shows that the existing design is adequate to accomplish mission objectives. However, several minor changes that would enhance the performance and the ability to monitor this performance are:

1) Incorporate the psi-2 angle counter in the PACE beam positioner by using the angle encoder register to count the angle. This change would save 300 components per quadrant.

2) The present sine wave generator may have capability beyond that required. A proposed change would use analog techniques to generate the required sine waves. Potential savings exist of over 200 components per PACE plus over 1 watt of power.

Jet Control Electronics (JCE)

JCE Circuit Design and Fabrication Status

Final circuits have been released. Modification and checkout of the cards for the advanced engineering model (flat-card version) has been completed.

Solenoid Driver Circuit Design and Fabrication Status

The final circuit has been released, and modification of the Advanced Engineering Model cards has been 75 percent completed. One of the four models to be delivered (for evaluation tests of the Marquardt valves) has been fabricated.

CENTRAL TIMING ELECTRONICS

Central Timer Circuit Design Status

The final design review for the central timer has been rescheduled for 11 October 1963. Long term core stability tests have been held up by extensive delays in getting cores wound. Tests should be renewed shortly, however. A specification covering the required central timer core type has been submitted to the Component Department for processing.

Squib Driver Circuit Design Status

The development of the squib driver circuit is nearing completion. Temperature tests will begin shortly.

The test mentioned in the last progress report to evaluate the use of 10-ohm CG 1/4 glass resistors as an additional safety fuse is partially completed. In the squib driver, these resistors would be overrated only if a transistor shorted. Resistors were tested in a vacuum chamber on 20 and 23 September. All resistors failed by increase in resistance greater than 10 kilohms. Data is being analyzed and will be available by mid-October.

Breadboard Model

Final checkout of the central timer breadboard model (minus the squib driver) has been completed and evaluation is proceeding. Temperature tests at the design temperature extremes (0° and +50°C) have been performed with no degradation in timer performance. Tests at extended temperatures are now being initiated. A flat card breadboard of one squib driver has been partially completed. When completed it will be mated with the command decoder and the central timer breadboards.

Product Design Status

All of the six timer module types have completed design and two have completed drafting. Specifications are presently being written for the unwound counter core, the wound counter core assembly, and the tuning fork. Some difficulty has been encountered in generating these documents because of uncertainties as to the environmental conditions at the unit mounting location.

Test Equipment Status

The design of the central timer unit tester has been started and is approximately 40 percent complete.

COLLINEAR ARRAY (CLOVERLEAF) RECEIVING ANTENNA

Advanced Engineering Model

Fabrication of the new array with a larger spacing between the cloverleaf segments will be completed soon. The center conductor in this array is made in segments that screw together so that different matching sections can be easily installed. A tentative matching section has been determined and will be checked in this array as soon as possible. The parts for a production model antenna have been fabricated. This antenna will be assembled with a matching section and tested during the next month.

Specifications

Test specifications for flight and prototype antennas are being written.

VELOCITY AND ORIENTATION CONTROL

Bipropellant Rocket Reaction Control

A program which provided for two propellant exhaustion tests on the engineering model was negotiated with the Marquardt Corporation during the last report period. Prior to conducting these tests it was necessary to increase the durability of the axial motor. This was accomplished by opening the fuel injector passage from 0.016 to 0.031 inch, thereby decreasing the fuel injector pressure drop. Although required durability was obtained, unstable combustion yielded erratic performance wherein specific impulse at the 5-pound thrust level varied from 190 to 260 seconds. A second modification was made to increase the fuel injector pressure drop slightly using a passage sized to 0.0225 inch. This resulted in a smoother burning configuration that delivers a steady specific impulse of 250 seconds and demonstrates a durability more than adequate for the two engineering model tests, each of which is more severe than the mission. The radial engine, which operates only in the pulsed mode, required no modification. For final engineering model radial and axial engine configurations and performances, see Table 4-1.

TABLE 4-1. ENGINEERING MODEL ENGINE

Parameter	Engine	
	Radial	Axial
Impulse, seconds		
Configuration 5	280	250
Configuration 4	262	258
Configuration 3	240	245
Injector orifice diameter, inches		
Fuel	0.016	0.0225
Oxidizer	0.019	0.019

The two propellant exhaustion tests were conducted on the engineering model, using the above modified engine in the axial position. The first test was completed satisfactorily and without incident. It was noted that the fuel depleted first and 3.75 pounds of oxidizer remained. During the second expulsion test the radial engine ceased to operate and the test was completed by firing the axial engine only. Again, fuel depleted first, but this time 1 pound of oxidizer remained. Data is currently being reduced from both propellant exhaustion tests. An analysis of the radial engine failure is being made. The most probable cause is felt to be the heavy teflon seat in the propellant valve. This seat has been known to cold flow and restrict propellant flow. Therefore, later models of the propellant valve incorporate thinner teflon seats that do not exhibit this tendency to restrict flow.

The Marquardt Corporation has been conducting a company-sponsored thrust chamber Research and Development program in support of the contracted Advanced Syncom effort. A number of tests have been made on coated molybdenum thrust chambers using a shortened combustion chamber with a premix section incorporated in the forward end. Specific impulse is 275 seconds at the 5-pound thrust level and 245 seconds at the 3-pound thrust level. Steady-state runs on the design accrued over 1-1/2 hours run time before burnout.

An internally coated tantalum-tungsten thrust chamber was fired for 1 minute, at which time a burnout occurred. It is believed the test setup, in which a highly reflective shield surrounded the engine, raised the chamber wall temperature an additional 300°F. Additional tests on this design are planned. A satisfactory method of increasing the outer wall emittance from 0.3 to over 0.7 is currently being investigated. Vacuum operation of a radiation cooled motor depends on maintaining a wall emittance of 0.7 or higher.

Selection of the thrust chamber design to be used in the follow-on program will be based on an evaluation of engine test results from the interim program as well as the Research and Development program.

TELEMETRY AND COMMAND

The block diagram of the telemetry transmitter, command receiver and hybrid balun position of the telemetry and command system is shown in Figure 4-10. The dual hybrid balun as shown in configuration form in Figure 4-11 is in process of fabrication. Figure 4-12 shows the general arrangement of the balun. The configuration of the 8-whip antenna system is shown in Figure 4-13. The command receiver telemetry transmitter and diplexer have been fabricated and tested and are ready for foaming and final test. Drafts of specifications have been completed for the receiver, transmitter, and diplexer.

Command Decoder Electronics

Command Decoder Digital Processor Status

The checkout of the command decoder digital processor is nearly complete, and no errors in design have been found to date. The configurations of the regulator drivers are now firm, and the preliminary design of the decoder output circuitry is being optimized for all circuitry which it must drive.

Filters and Detectors

Several different types of cores are being evaluated to determine the best core for the decoder filters. The preliminary design of the filters and detectors will be completed shortly.

Telemetry Encoder

Circuit Design Status

Preliminary designs of the telemetry encoder circuits are about 80 percent complete. The remaining designs will be completed about mid-October.

Sun sensor pulses ψ and ψ_2 will be telemetered in real-time for use in the backup ground control mode of the pulsed jet system. This will be accomplished by direct phase-modulation of the 136-mc telemetry carrier. The ψ and ψ_2 pulses are of the same polarity but different amplitudes.

An optimum method for telemetering solenoid operation is under investigation and a decision will be reached within the next period.

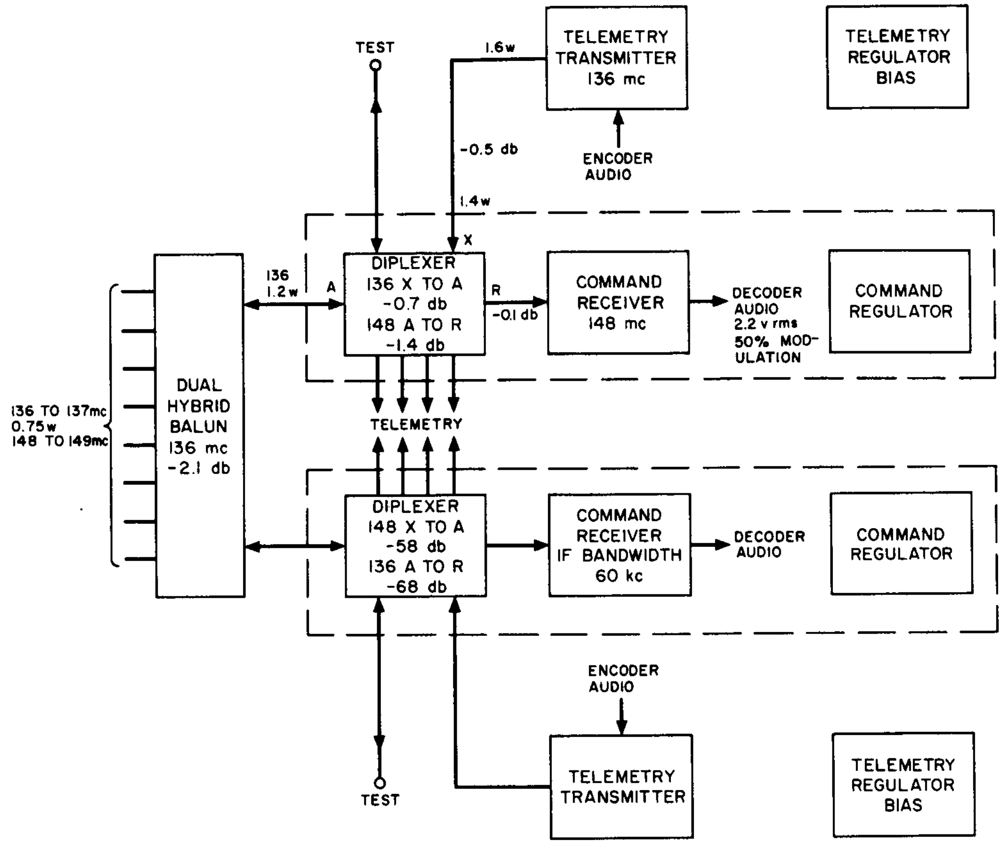


Figure 4-10. Receiver-Transmitter Subsystem Telemetry Command

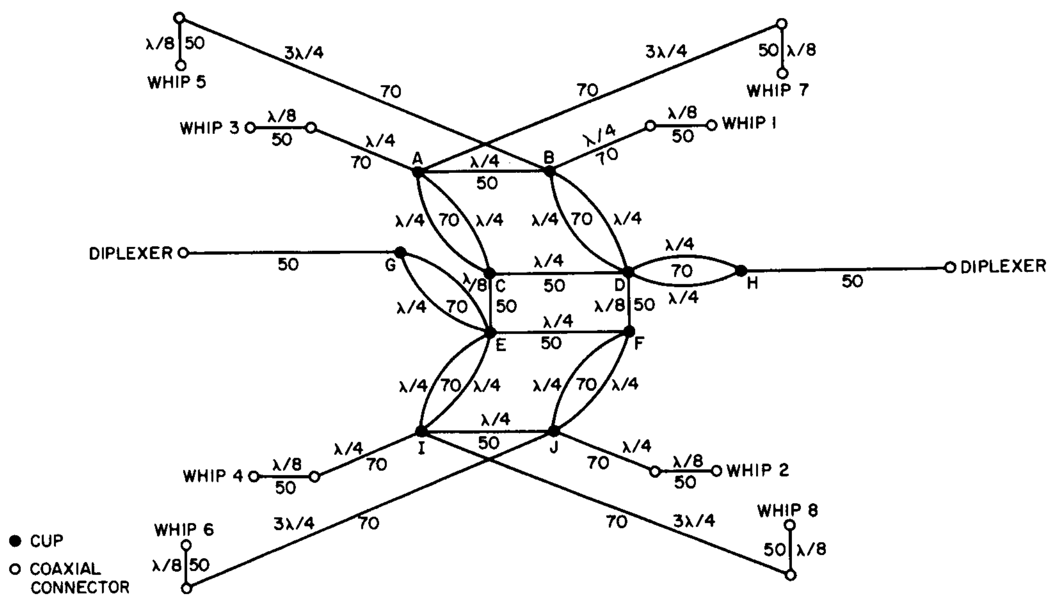


Figure 4-11. Dual Hybrid Balun Telemetry and Command

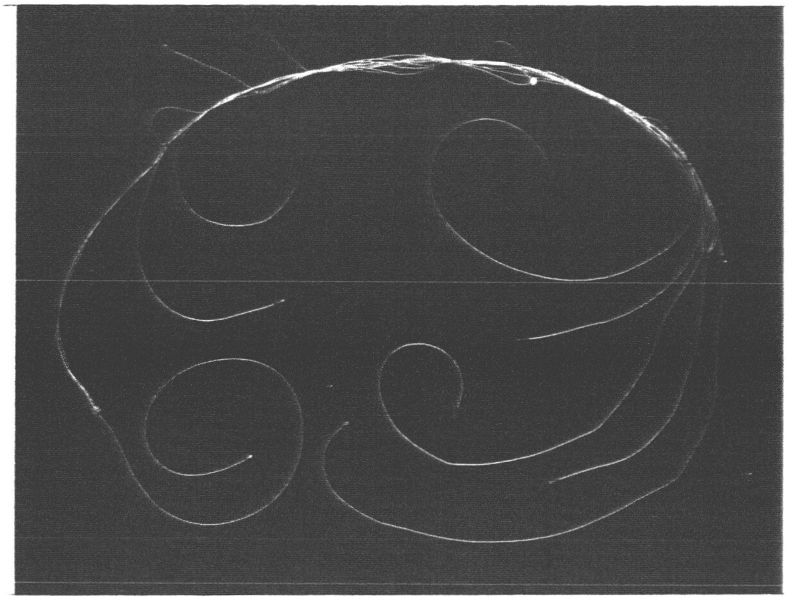


Figure 4-12. Dual Hybrid Balun

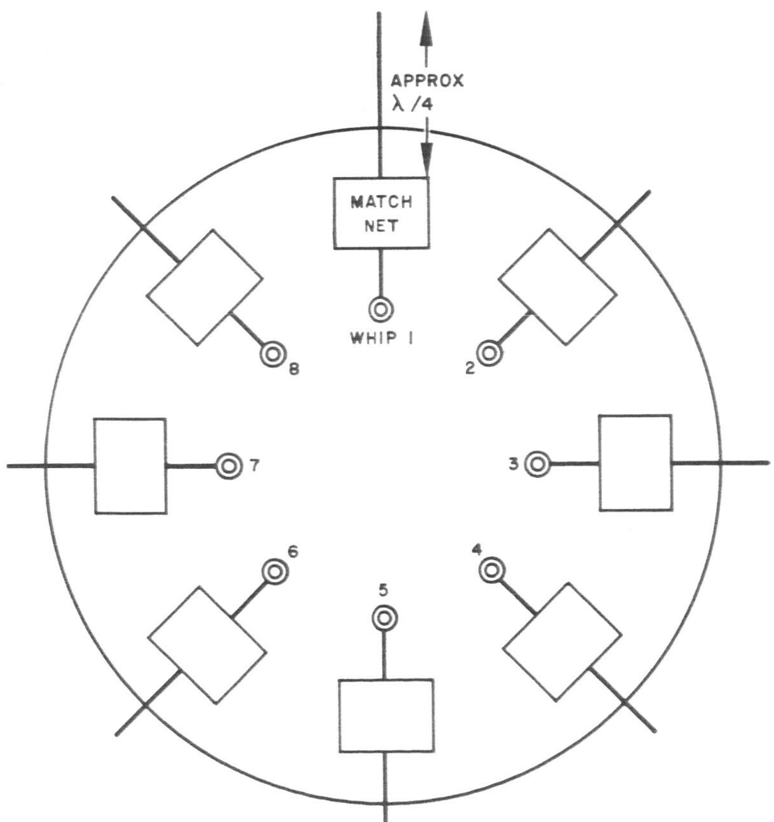


Figure 4-13. Eight-Whip Antenna System Telemetry and Command

Breadboard Status

The fabrication of the encoder breadboard is approximately 30 percent complete.

Operation and Telemetry Indications of Squib-Firing and Solenoid Valve Circuits

Twelve squib driver circuits are used (Figure 4-14) to fire the apogee motor, release the axial jet locking pins, and open the normally-closed valves. Three commands are available to accomplish these functions. One command will be used for apogee motor firing. The choice of combinations for the other commands is not apparent. Either one unit, i.e., 2 pin-pullers and 2 valves, can be activated with each command or all pins can be released with one command and all valves with the other. Assuming that there are no squib firings until after apogee motor burn, there appears to be no advantage either way. For a non-nominal transfer orbit where an RCS firing might be required before apogee motor firing, two choices are available:

1) Release a complete unit with each command. This will allow both spin speed velocity and orientation control but can possibly result in losing the unit at apogeee motor firing due to the unlocked axial jet.

2) Release the valves with one command and the pin-pullers with the other. By releasing the valves, velocity and orientation can be controlled but not spin speed; however, both units should survive apogee motor firing.

The second choice is the most desirable, as the most probable error during the transfer ellipse will be one of orientation. Therefore, the squib firing commands are utilized as follows:

Command 1 — Fire both apogee motor squib drivers

Command 2 — Fire all four spin puller squib drivers

Command 3 — Fire all four valve release squib drivers.

Telemetry (TM) indications of squib firings and solenoid valve operation are required at the ground station. As presently instrumented, each solenoid driver activates one fuel and one oxidizer valve. A TM indication of each solenoid driver output is a required minimum. This will be a real time indication most probably instrumented by AM modulation of the execute pulse with a different modulation level for each driver. Squib firing ideally should be indicated by an output from a mechanical device which is a positive indication (for all squibs except apogee motor) of proper action. If a mechanical indication is not practical squib firing can be inferred by utilizing an output from each driver circuit to AM modulate the execute pulse just as for solenoid valves. Again a different level can be utilized for each output. These levels can duplicate those used for solenoid operation since the two events do not occur at the same time. In the case of any doubt, the time delay in the squib drivers will differentiate between the two signals when related to the time of start of the execute pulse.

ELECTRICAL POWER SYSTEM

System Test

Checkout of the basic electrical controls associated with the power system analog has been completed. System checkout is scheduled for completion during the first portion of the next report period with system tests to start immediately thereafter.

Solar Panel Fabrication Status

Solar Cell Assembly Machine

The solar cell assembly machine (Figure 4-15) is now in final assembly with checkout scheduled for the week of 6 October 1963. Panel fabrication is to be started approximately 10 days later.

Procurement Status

Battery Cells

Battery cells have been ordered from Gulton Industries and the General Electric Company with deliveries to be made by 15 October 1963.

Solar Cells

Solar cells for the first solar panel to be fabricated using the automatic assembly equipment are to be delivered from Texas Instruments and Heliotek prior to 15 October 1963.

STRUCTURE

Structural Engineering Design

The torus ring, which supports the forward components, has been moved approximately 3.5 inches aft to station 56.6. The sun sensor supporting structure and axial jet mounting brackets have been redesigned extensively. The changes were made to reduce weight in an attempt to improve the inertial roll-to-pitch ratio of the spacecraft.

Studies were made on alignment mechanisms for the sun sensors and axial jets to ensure proper orientation with the spacecraft spin axis and center of gravity. The center structure was shortened approximately 0.5 inch to

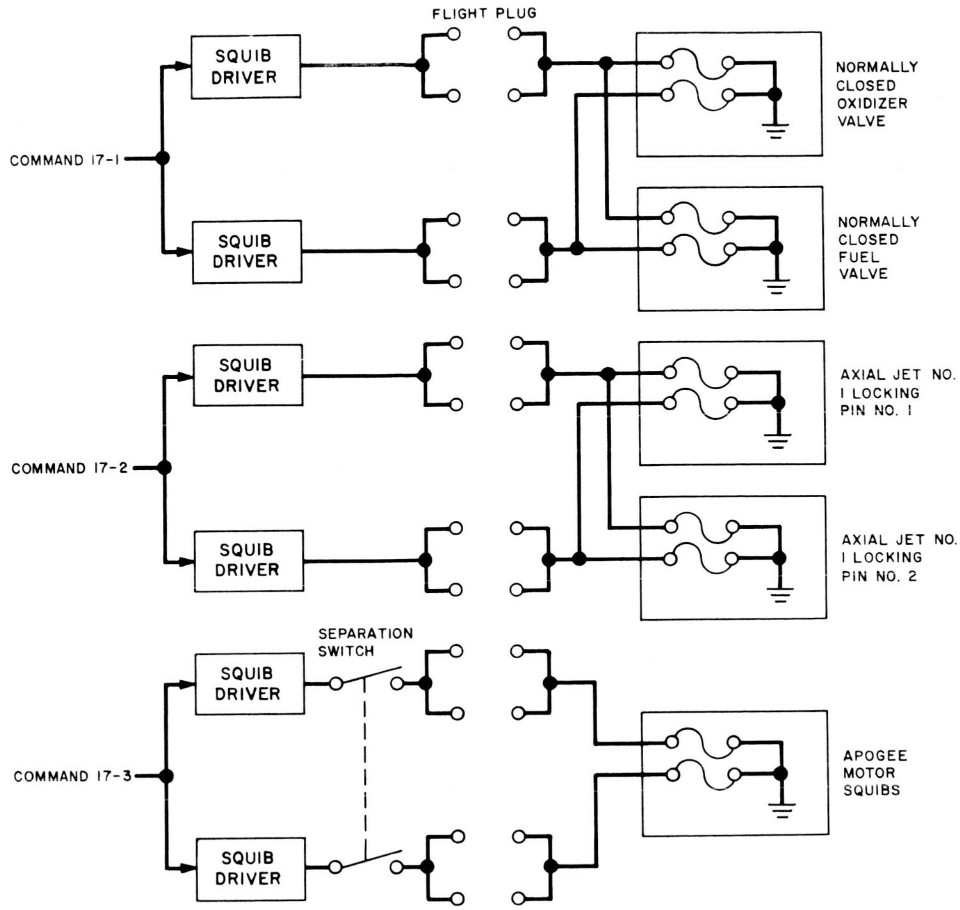


Figure 4-14. Squib Firings for One Unit of Reaction Control Subsystem

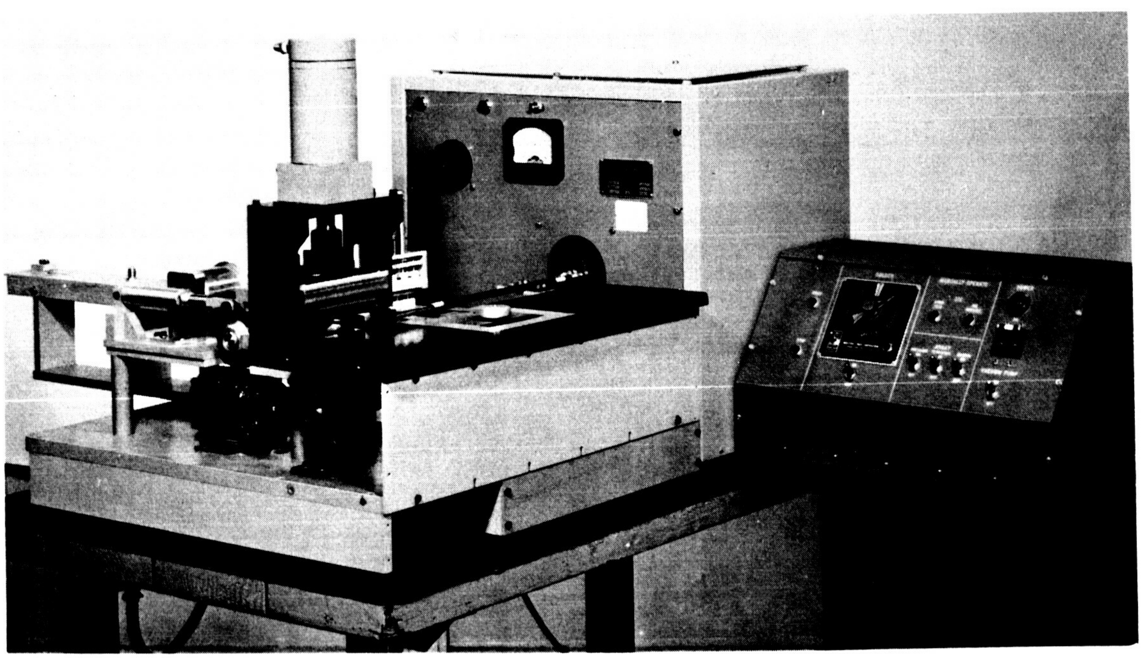


Figure 4-15. Solar Cell Assembly Machine

reduce weight of the thrust tube and stringers in a further attempt to improve the roll-to-pitch ratio.

Layout work is nearing completion on the propulsion system tank mounting brackets, radial jet mounting brackets, and alignment mechanisms. Provisions have been made for the location and installation of the valves, transducers, lines, and associated attachments.

In the aft structure, the insulating ring between the rocket motor and the thrust tube has been removed as a result of preliminary thermal analysis. The outboard solar panel attachments have been moved 2 inches toward the center in conjunction with the movement of the torus ring. Solar panel mounting hardware was finalized with some late changes to the attaching clips. Detailed study is under way to package the batteries and locate as many as possible on the periphery of the vehicle interdigitated with the gas tanks at the spacecraft longitudinal center of gravity.

The revised general arrangement is shown in Figure 4-16. Figure 4-17 shows an exploded view of the spacecraft structure illustrating the principle of installation of the bipropellant system.

Structural Redesign

A major structural redesign is being considered to increase the critical roll-to-pitch ratio and reduce structural weight. The considered configuration would delete the aft ribs and carry loads through the reinforced sides or panels of the electronic component packages. Some redesign of the component packages would be necessary. The modified shape would result in approximately a 15 percent increase in the volume of the packages. Gas tank mounting would have to be revised and batteries repackages and relocated.

A preliminary layout was released to the Mass Properties section for evaluation of center of gravity, and roll-to-pitch ratio. Further work is being delayed pending their evaluation.

Engineering Drawings

The solar panel, attaching study, slide, and clip drawings have been released to the shop and parts are being fabricated for vibration tests. Approximately one-third of the attaching brackets have been released. Representative brackets are to be used in the vibration tests.

Eight electronic unit space envelope drawings have been completed and are awaiting appropriate approvals before release.

Progress has been maintained on the basic Advanced Syncom structure. Long lead items, including the frame ring and thrust ring blank, have been released. The aft structure assembly is 80 percent complete. Drawings are nearing completion on the center section thrust tube and stringers and the

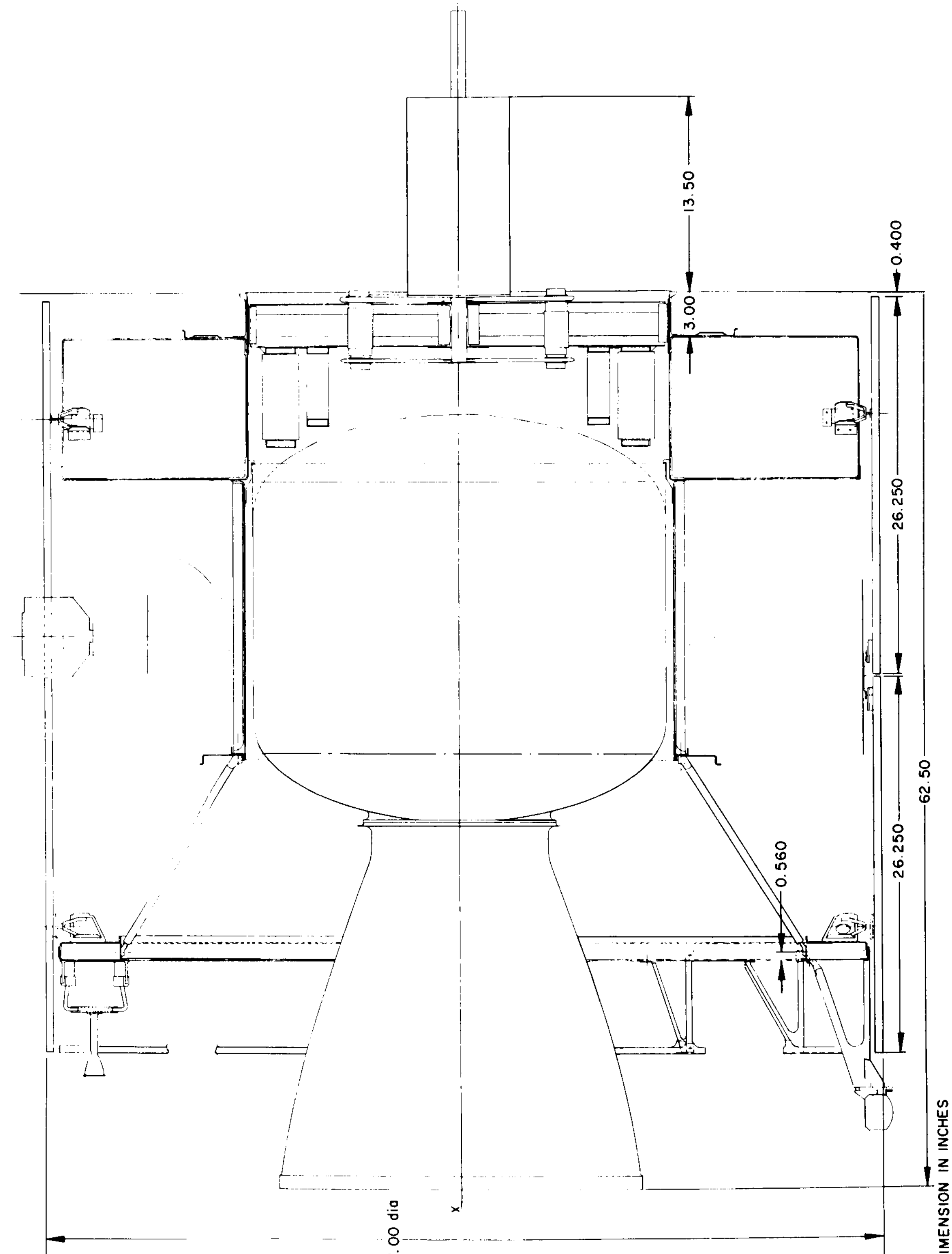


Figure 4-16. Advanced Syncom General Arrangement

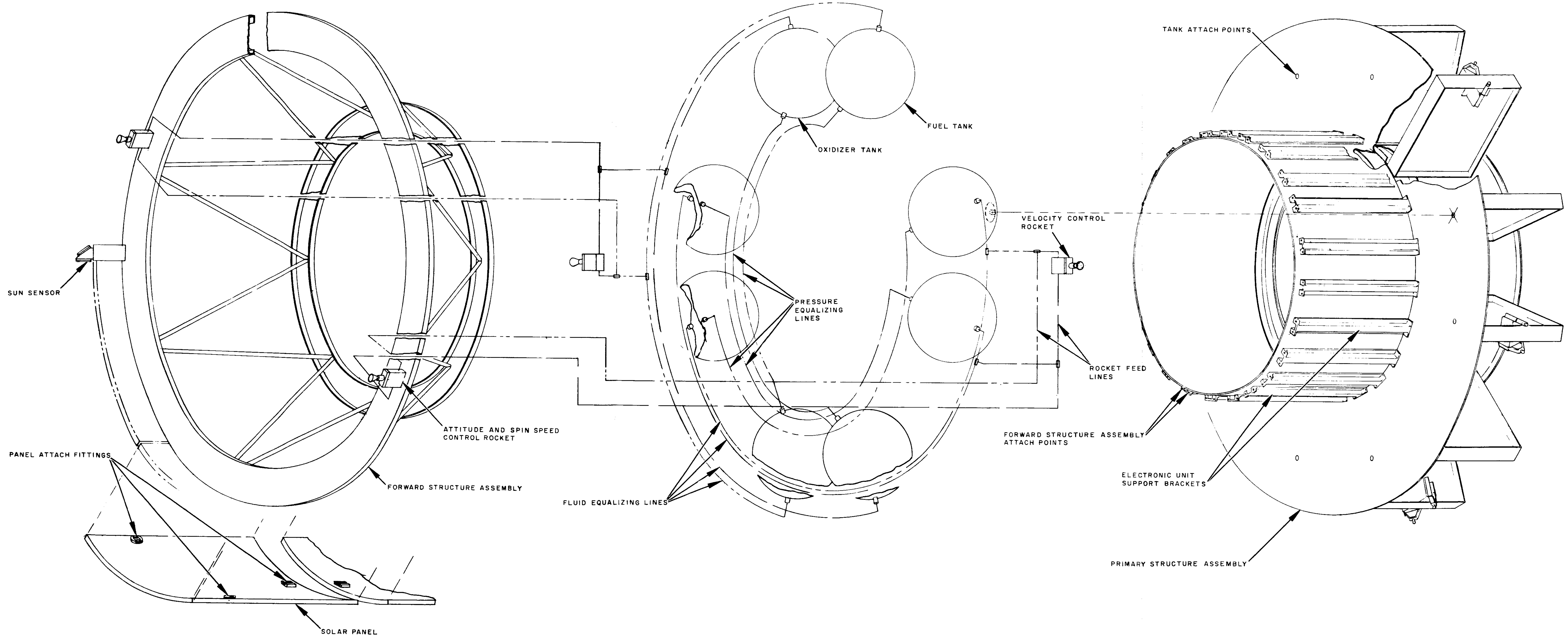


Figure 4-17. Advanced Syncom Exploded View

forward torus ring. Details and assembly of the forward truss are nearly completed.

Structural Analysis

Solar panel brackets have been re-analyzed because of structural redesign. Basic structural components are under analysis in order to meet drawing release schedules.

Mass Property Analysis

Revised configuration studies of the spacecraft, conducted to obtain higher roll-to-pitch moment-of-inertia ratios, again accounted for the major portion of the mass property control effort. Three configurations were investigated before the last reporting period. During this period, five additional configurations have been analyzed to achieve acceptable roll-to-pitch ratios. The roll-to-pitch ratio for the final orbit condition increased from 1.11 to 1.13 before decreasing to 1.08. However, relocation of the batteries to the longitudinal center-of-gravity plane increased the roll-to-pitch ratio to 1.11. Principal spacecraft configuration changes that have affected the roll-to-pitch ratio since last reported are:

1) Decrease in electronic quadrant weight

2) Decrease in main wire harness weight

3) Substitution of Hughes-calculated values for JPL apogee motor estimates

4) Increase of forward truss tubing wall thickness

5) Increase of forward torus ring gage

6) Distribution of balance adjustment forward and aft to reflect realistic pitch inertia

7) Increase of thermal shield weight

8) Relocation of batteries to longitudinal center-of-gravity plane.

The current mass property data and a subsystem weight breakdown for the Advanced Syncom HSX-302-T2 is shown in Table 4-3. Detailed weight changes from the August 1963 report are shown in Table 4-2.

TABLE 4-2. WEIGHT CHANGES

Description of Change	Weight Change, pounds
Electronics	(-4.5)
Revised estimate for electronic quadrants	-4.2
New estimate for rib mounted units	-0.5
Revised estimate for multiplexers	+0.2
Wire Harness	(-3.9)
Redesigned main wiring harness	-8.7
Added electronic quadrant harness	+4.8
Propulsion	(-8.3)
Transferred excess from Hughes calculations to expendables	-8.3
Structure	(+8.7)
Redesigned solar panel supports — rotated 22-1/2 degrees	+0.3
Redesigned thrust tube stiffeners to support electronic quadrants	+0.8
Redesigned radial engine support structure	+2.5
Redesigned control system tank supports	+2.7
Increased wall thickness of forward truss	+0.4
Increased gage of forward torus ring	+2.7
Revised estimate for miscellaneous supports	-0.7
Miscellaneous	(+3.0)
Redesigned thermal shield	+3.0
Ballast	(-3.3)
Decreased to maintain maximum spacecraft weight	-3.3
Apogee Motor Expendables	(+8.3)
Transferred from propulsion	+8.3
Net Weight Change in Payload at Separation	0.0

TABLE 4-3. CURRENT WEIGHT STATUS HSX 302-T2

Subsystem	Δw* pounds	Current Weight, pounds	Target Weight, pounds	ϕ**	θ***
Electronics	- 4.5	178.5	157.4	0.293	0.118
Wire harness	- 3.9	16.0	16.4	0.026	0.011
Power supply	0	112.7	112.5	0.185	0.074
Controls (dry)	0	53.2	49.9	0.087	0.035
Propulsion	- 8.3	102.6	102.0	0.168	0.068
Structure	+ 8.7	104.0	94.2	0.170	0.069
Miscellaneous	+ 3.0	17.8	14.5	0.029	0.012
Ballast	- 3.3	25.2	62.5	0.041	0.017
Final Orbit Condition	- 8.3	610.0	609.4	0.999	0.404

	Current Weight, pounds	Z-Z inches	$I_{z-z'}$ slug-feet^2	$I_{x-x'}$ slug-feet^2	Roll-to-Pitch Ratio
Final Orbit Condition	610.0	24.07	57.04	51.57	1.10
N_2 pressurant	2.6				
N_2H_3-CH_3 fuel	51.6				
N_2O_4 Oxidizer	81.9				
Total at Apogee Burnout	(746.1)	24.07	70.94	58.52	1.21
Apogee motor propellant	752.3				
Apogee motor expendables	19.6				
Total Payload at Separation	1518.0	23.19	87.74	75.57	1.16

*Change in subsystem weight since last report.
**Ratio of subsystem weight to final orbit condition weight.
***Ratio of subsystem weight to total payload at separation.

Thermal Control

Thermal System Analysis

A thermal analysis of the Advanced Syncom spacecraft has been performed with emphasis toward determining:

1) Spacecraft orbital bulk temperature variations

2) Vehicle axial gradients at extreme sun positions

3) Potential need for active thermal control system

4) A general overall thermal design concept

Analyses have been made using a 2-node analytical model. Results have yielded vehicle bulk and solar panel temperatures at low and high power cases for three spacecraft configurations varying from the Syncom I thermal control concept to the concept of complete isolation of the spacecraft ends from deep space. A preferred thermal control system has resulted, and the recommendation has been made to incorporate a completely passive thermal control technique into the Advanced Syncom vehicle design. Limiting conditions for the recommended design have been specified, and major areas of potential problems and uncertainties have been discussed.

A 2-node analytical model of the Advanced Syncom spacecraft was used in determining orbital temperature variations. The model considered a cylindrical vehicle as one node and cylindrical solar panels as the other. The resulting equations were solved for vehicle bulk and solar panel temperature for high and low power modes, solar angles of 90 ± 25 degrees, and three configurations varying from the Syncom I concept of enclosed ends to the idealized concept of perfectly insulated ends. Results are shown in Figure 4-18 for the three configurations chosen at the high power mode condition. For the perfectly insulated and semi-insulated concept, the vehicle bulk temperature is always above the solar panel temperature; whereas for the Syncom I type of thermal design this is true only at the off normal sun angles. In addition, the vehicle bulk temperature increases as the ends of the vehicle become more isolated from outer space.

An active thermal control concept has been considered for use on Syncom in the event that reasonable temperature swings of system components cannot be obtained passively or that external surface thermal property degradation is so great over the long time period of the spacecraft as to seriously perturb temperatures. In the investigation it was determined that for a spacecraft geometry such as Syncom (wherein the sides of the cylinder comprise the solar array and the ends are required to isolate the vehicle from space to achieve reasonable bulk temperature) an active thermal control system could only be useful if it were physically located on the same surface as the solar cells. Therefore, only if the heat-absorbing or heat-radiating ability of the sides of the cylinder were variable could the controllable swing in temperature be significant and even then only at the expense of significant increase in length (and consequently weight) of the spacecraft. It was finally determined that the main objectives of an active thermal control system could be established at least in part with a properly designed and significantly lighter passive thermal control concept.

In specifying the thermal control system for the Advanced Syncom spacecraft, several objectives are stated:

1) To provide an average vehicle bulk steady-state orbital temperature of 70°F for the life of the spacecraft

2) To minimize changes from this average temperature during orbital operation

3) To minimize temperature gradients within the vehicle induced by changes in solar angle within the range of 90 ±25 degrees.

From Figure 4-18 it can be seen that the vehicle bulk temperature can be made to vary from 90°F to 64°F depending on the degree of isolation of the end planes from space and on the solar angle. The vehicle axial gradient can vary from approximately 115°F (see Figure 4-40 of the August Monthly Report) for the Syncom I type of design to 0°F for the idealized configuration of perfectly insulated ends. Although the effects of space conditions on surface properties of materials is relatively unknown, consideration must nevertheless be given to this in selecting a thermal design. Finally, the internal thermal coupling of the vehicle components must be included at least in general terms in specifying a recommended thermal design concept.

The resultant recommended spacecraft passive thermal design consists of:

1) Semi-insulated ends — This concept requires that the end planes of the vehicle (i.e., the ground plane and thermal barrier) be approximately normal to the solar panels, possibly insulated from the vehicle structure through the use of several layers of thermal radiation shielding, and containing the minimum of discontinuities (i.e., cracks, cavities, etc.). This concept will inhibit the loss of energy from the vehicle at all times and reduce the absorption of solar energy at the illuminated end plane, resulting in an average bulk and solar panel temperature similar to Figure 4-16. In addition, the axial temperature gradients within the vehicle will be reduced considerably from that previously reported for the Syncom I design concept. This proposed design will also reduce the vehicle temperature dependency on the external surface properties of the end planes to a negligible amount, thus isolating the surface property degradation problem to only the solar panel properties.

2) Soft mounting for passive components — To reduce to a minimum the temperature fluctuation of passive (non-heat generating) components such as tanks, batteries, etc., during short time spacecraft transients caused by

eclipses, power transients, or motor firings, it is recommended that insulative types of mounts be utilized. In active components however, hard mounts are preferred so that the vehicle structure can remove dissipated energy rapidly from local heat generating sources.

3) Localized radiation shielding where required — In the areas of the spacecraft where high heat fluxes over short periods of time are experienced such as in the vicinity of the apogee motor or reaction control jets, it may be necessary to protect surrounding equipment with radiation shielding to prevent momentary overheat of any vehicle components or systems.

With the selection of a completely passive thermal control system for the Advanced Syncom spacecraft, several potential problem areas and system limitations must be considered.

1) Quoted vehicle bulk temperatures apply to average structural mounting surfaces and passive equipment. Active heat dissipating elements must be mounted in such a way as to minimize temperature rises at local hot spots.

2) The exterior surface property degradation attributable to space effects is unknown. Although the proposed thermal design isolates this potential problem to the solar panels, it is possible that a significant thermal effect could be experienced. However, since the solar panels are nearly black in radiation properties, it is not felt that the vehicle bulk temperature could rise more than approximately 20° F above design values. The most severe imaginable drop in vehicle bulk temperature caused by surface damage is in the 30 to 40° F range. Neither of these potential perturbations seem catastrophic in itself. Further assurance is provided in the apparent tendency toward thicker cover glass for the solar cells.

3) Since no active thermal devices are specified for the Advanced Syncom design, the quoted bulk temperature range applies only in the region of solar angles between 65 and 115 degrees in reference to the positive spin axis. No provision is included for thermal control outside of this solar region.

4) Vehicle internal temperatures during eclipse transients are unknown at this time. The degree of thermal coupling between the vehicle and solar panel will determine the rate of bulk temperature drop with time.

5) External motor firing effects are as yet, unknown. The plume expansion for both the apogee motor and the reaction control jets has been partially investigated, but present state-of-the-art knowledge of the total effects is definitely not complete. Further analysis and test is required to establish thermal protection requirements for the thermal barrier and solar panels.

Temperature Sensor Location

Coordination meetings have been held to discuss the location of Advanced Syncom temperature sensors. A total of 16 sensors will be included on the vehicle. Tentative general location of the sensors has been established and is shown in Table 4-4. The fuel and oxidizer tank sensors and traveling-wave tube sensors are repeated in each of the two telemetry encoders, thus providing 11 temperature readings with each encoder.

TABLE 4-4. TEMPERATURE SENSOR DESCRIPTION

Sensor Description and Location	Number of Sensors	TM Encoder Number
Reaction control system – fuel and oxidizer tanks	4	I and II
Near traveling-wave tube collector – ribs 3 and 9	2	I and II
Solar panels		
Near radial jet 1	1	II
Near either end of vehicle	1	I
Antenna cruciform	1	I
Sun sensor	1	II
Aft bulkhead	1	I
Battery	1	I
Apogee motor mounting point	1	II
Radial jet number 1 mounting surface	1	II
Forward shelf near TM transmitter	1	II
Axial jet 1 mounting surface	1	I

Apogee Motor Insulation Analysis

The preliminary two-fold thermal analysis of the apogee motor insulation requirements has been completed. The steady-state analysis in which the heat leak properties of the apogee motor mounting ring during normal orbital operation were evaluated indicated that heat losses through the attach point and out the apogee motor nozzle were small (approximately 1 watt) even without the insulating ring. Consequently, the requirement of an insulating mount for prevention of heat losses from the vehicle cannot presently be justified.

The second phase of the analysis included investigation of the vehicle warm up characteristics during the apogee motor firing transient. Based on the motor temperature characteristics given and a somewhat rough nodal model (refer to Figure 4-41, August Monthly Report), the vehicle temperature response is shown in Figure 4-19 for the noninsulated configuration. Although the analysis was only approximate in that the network was somewhat coarse and the nodal points did not all reach their maximum temperatures in the chosen time period for the transient analysis, it is felt that the results cannot justify the need for an insulating ring at the apogee motor mounting point.

Antenna Analysis

The apogee motor insulation analysis has been extended to include the antenna and cruciform portion of the spacecraft (see Figure 4-20). The intent of this analysis is again twofold:

1) To determine temperature range of antenna and cruciform region during normal orbital operation

2) To determine the need for radiation insulation between the apogee motor and cruciform for protection of the antenna components during apogee motor firing

Network parameters are currently being determined for ultimate computer solution of both the steady-state and transient problems.

Apogee Rocket Engine

The apogee rocket engine, under development at the Jet Propulsion Laboratory, utilizes the design concepts and materials that have been successfully proven in the Syncom I spacecraft.

The first heavy-wall engine was tested on 22 August 1963 at sea level conditions. All test objectives were achieved and the engine performed as predicted. Action time was 39. 2 seconds with a maximum chamber pressure of 240 psia occurring at 29. 0 seconds. No thrust data reduction was accomplished as flow separation in the nozzle rendered thrust data invalid. A circumferential crack, possibly occurring during cooldown, was noted in the thread relief of the graphite throat insert.

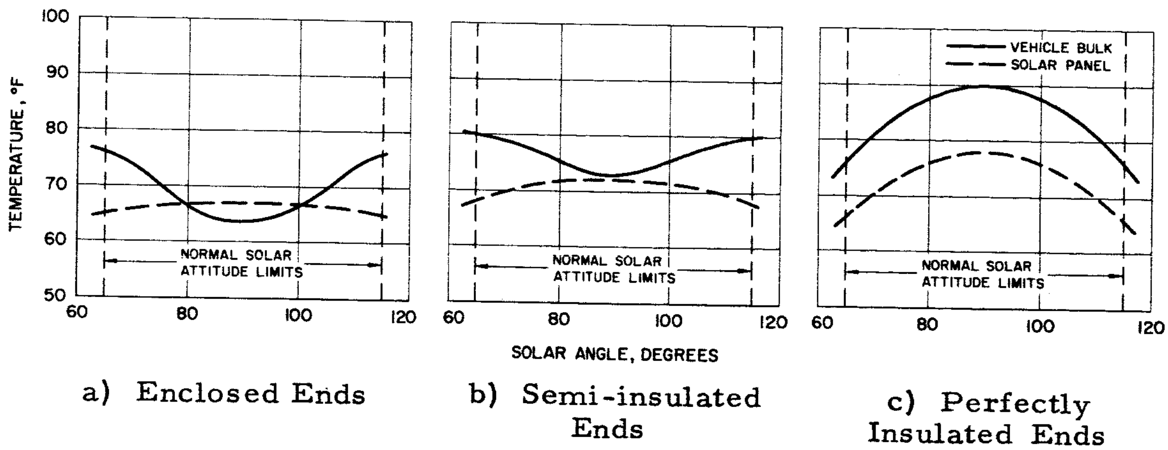


Figure 4-18. Vehicle End Geometry Versus Temperature

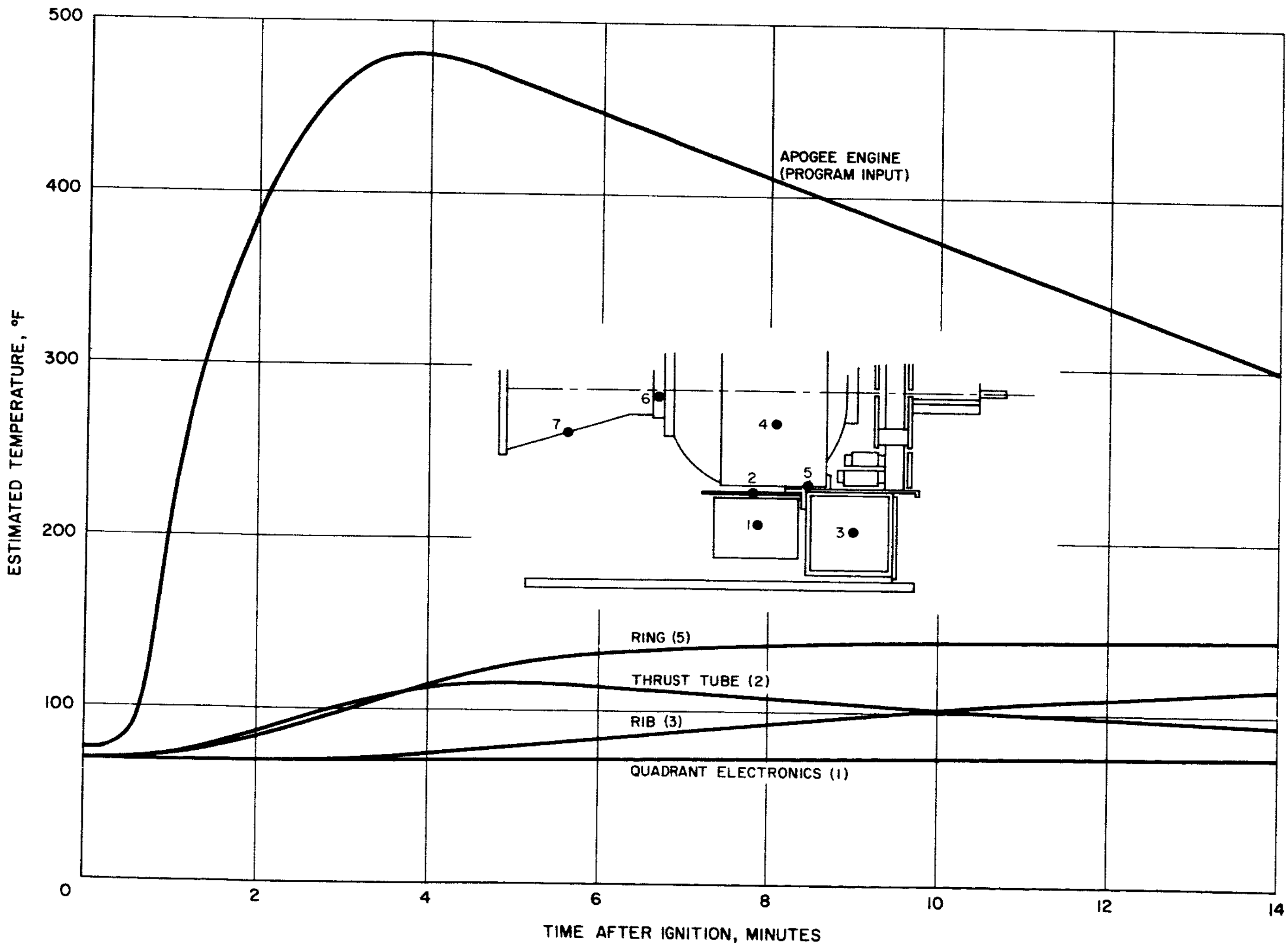


Figure 4-19. Estimated Temperature Response During Apogee Engine Firing

The second test in the development series was made on 24 September 1963. The engine and propellant loading were identical to that of the first engine except for the nozzle, which was a lightweight sea level design. The engine again performed as predicted; however, data reduction is not complete at this time. No cracking of the throat insert occurred. The third test in the series will be conducted on 1 October 1963 at EAFB. The 150-gallon propellant mixer is to be in operation by December 1963 and will permit the manufacture of engines utilizing one propellant batch instead of the three batches currently required.

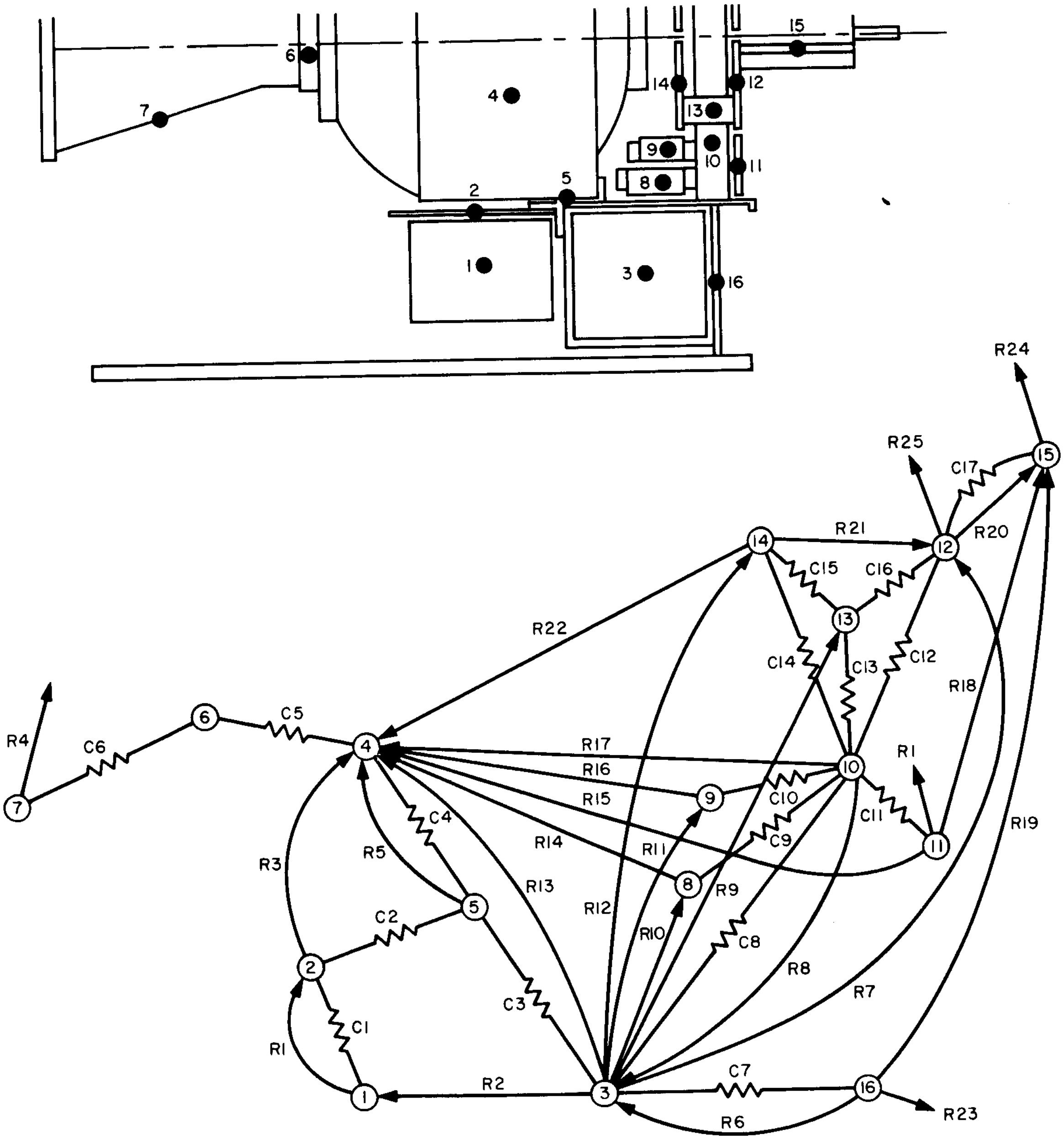


Figure 4-20. Vehicle Analytical Model Including Antenna Geometry

5. SPACECRAFT RELIABILITY AND QUALITY ASSURANCE

FAILURE MODE ANALYSIS

The system and subsystem failure mode analysis is complete and is being published. It has shown only two areas where a single failure could be catastrophic to the communication system. One is an open or short between the receiving antenna and the multiplexer; the other is an open or short between the transmitter multiplexer and the power splitter.

QUALITY CONTROL STATUS REPORT

The quality assurance engineering effort during the present phase of the Advanced Syncom project has been concentrated on a quality program for the development and launch program. The following tentative list of Quality Control Instructions (QCIs) and Inspection Planning Sheets for Hughes Processes (HPs) will assure the quality of the deliverable hardware.

Document Number	Title	Status
Quality Control Instructions:		
3.13-0	Inspection Check List	Released for this phase of the program
3.13-1	Quality Requirements	Released for this phase of the program
3.13-2	Screening Assist Work Authorizations	Preliminary draft complete
3.13-3	Screening Purchase Orders	Preliminary draft complete
3.13-4	Receiving Inspection of Purchased Parts	Waiting for project parts program
3.13-5	Bonded Stores Inspection	Preliminary draft complete

Document Number	Title	Status
3.13-6	Screening Work Orders	Preliminary draft complete
3.13-7	Control of Parts Pending Release of Released Prints	Preliminary draft complete
3.13-8	Control of Nonconforming Supplies	Waiting for contractual requirements
3.13-9	Soldered Module Inspection	Preliminary draft complete
2.1-2	Etched Circuit Boards, Inspection of	Released
2.1-5	Inspection of Micro Resistance Welding	Released
2.1-13	Soldering High Reliability Connections per NASA MSFC 158-B	Released

Inspection Planning Sheets for Hughes Processes:

4-99	Plating	Pending
4-112	Painting	Pending
4-142	Vacuum Deposit	Pending
9-24	Flux Cleaning	Pending
11-24	Dip Brazing	Pending
11-39	Welded Modules	Complete
16-41	Adhesive Bonding	Complete
16-91	Foam in Place	Pending
No HP Number	Electron Beam Welding	Pending
No HP Number	Installation of Feedthrough Capacitors	Pending
No HP Number	Welded Module and Board Assemblies	Complete

The supplier control task is continuing at a reduced level. The following represents the supplier effort for this reporting period.

Marquardt Corporation – Bipropellant Control System

The system was tested to Marquardt Test Procedure 0013 to comply with Hughes statement of work. Test data on the tape recording was not clear and a retest was required.

The system was retested to MTP 0013 revealing that performance of the radial engine did not meet specification requirements. Chamber pressure decayed in excess of the specification tolerance. A complete analysis of this failure will be conducted by Marquardt Engineering.

Semiconductors

Six facility surveys were performed during this period:

1) National Semiconductor Corporation, Danbury, Connecticut

2) Sprague Electric Company, Concord, New Hampshire

3) Crystalonics, Inc., Cambridge, Massachusetts

4) Westinghouse Electric, Youngwood, Pennsylvania

5) Siliconix, Inc., Sunnyvale, California (resurveyed)

6) Dickson Electronics, Inc., Scottsdale, Arizona

Corrective action requests are in process and will be forwarded to those facilities with a conditional or disapproved rating.

Passive Devices

Corrective action requests are in process and will be forwarded to facilities with a conditional or disapproved rating. In-process inspection is being performed as required on the items being fabricated during this phase of the program.

6. MATERIALS, PROCESSES, AND COMPONENTS

DESIGN AND QUALIFICATION

The preparation of parts specifications and coordination of their requirements with vendors is progressing. Although the parts list is not complete, 45 of the 73 items listed have been qualified and specifications have been released. Preliminary specifications for 25 of the balance have been prepared (with a preceding "X" until the evaluation tests have been completed). Numbers have now been assigned to the other three and the specifications are being prepared.

The requirements for magnetic parts have developed slowly, in some cases requiring the design and construction of several modifications for circuit tests before the final design could be determined. Electrical designs of most of the magnetic parts exist or are in process, but final product design and procurement specifications are not complete.

PARTS SPECIFICATIONS

Several component specifications being prepared for Advanced Syncom are presented here. The four documents are selective examples of the entire specification program.

Semiconductors

A new general specification, covering reliability requirements for space environment, has been prepared for procurement of semiconductors for Advanced Syncom. The specification is a standard format and will be accompanied by several tables establishing exact requirements for a given part.

It is expected that existing 988XXX basic specifications will gradually be replaced with the above format. In the interim, procurement of three-fourths of the Advanced Syncom requirements will be made with the basic specifications, modified by an addendum that will result in the same total effect as the standard specification. The addendum will consist of extractions from the standard specifications; its preparation is not complete at this time.

Status Summary

Transistors:

Basic specification format	13	Addendum required	13
General specification format	7	Completed	4

Diodes:

Basic specification format	14	Addendum required	14
General specification format	8	Completed	4

1. SCOPE

1.1 This specification covers the general requirements and test procedures for semiconductor devices suitable for use in spacecraft designed for long life expectancy. Special requirements are imposed to provide maximum quality and to assure high-performance reliability.

2. APPLICABLE DOCUMENT

2.1 The following documents, of the latest issue in effect, shall apply to this specification to the extent specified herein:

Military

MIL-STD-202	Test Methods for Electronic and Electrical Component Parts
MIL-STD-750	Test Methods for Semiconductor Devices
MIL-S-19500	Semiconductor Devices, General Specification for

National Aeronautics and Space Administration

NPC 200-3	Inspection System Provisions for Suppliers of Space Materials, Parts, Components and Services

Hughes Aircraft Company

988999	X-Ray Inspection Procedures for Semiconductor Devices

3. REQUIREMENTS

3.1 General.- The semiconductor devices shall meet the requirements specified herein and in the applicable specification for the individual device.

3.2 Marking.- Each semiconductor device shall be clearly marked with the manufacturer's name and/or trademark, the manufacturer's part number, and the serial number (see 3.3). (Devices too small to contain the above information shall be packaged individually, and each package shall be marked as specified above.)

(a) Diodes: The cathode end of diodes shall be identified by a band or dot or by means of the conventional diode symbol marked on the body of the device. Alternatively, the manufacturer's part number may be omitted, in which case the diode shall be marked with color-coded bands representing the numerical digits in the manufacturer's part number and located near the cathode end.

(b) Additional, Special, or Alternate Marking.- Additional, special, or alternate marking shall be as specified in the individual detail specification.

All marking shall remain legible after the completion of all tests.

3.3 Serialization.- Each device which successfully meets the requirements of the Group A screening tests prior to the X-ray examination shall be assigned a unique serial number. The serial number shall be stamped or printed on the body of the device, or printed on pressure-sensitive tape which shall be affixed to the body. When tape is used to identify the device, the tape shall be capable of withstanding an ambient temperature of 150° C and all of the tests specified, without losing adhesion or deteriorating. All test data furnished in accordance with this specification, and relating to any semiconductor device, shall be identified by means of the serial number assigned to the device.

3.4 Leads.- When the devices are equipped with wire leads, the following requirements shall apply, unless waived in the individual detail specification:

3.4.1 Material and Finish.- The lead material and finish of the entire shipped lot shall be homogeneous and shall be as specified in the individual detail specification. A certified statement listing the composition of the lead material and the type and thickness of the finish shall be prepared and submitted by the manufacturer in accordance with 4.3.8.4

3.4.2 Samples.- Five samples of the leads used in the manufacturer of each shipped lot shall accompany each shipment. The samples shall be in the form of rejected headers, electrically rejected units, or lead clippings at least 0.5 inch long.

3.5 Construction.- When inspected as specified in 4.4.3 (i), there shall be no evidence of foreign particles within the device or misalignment of the internal structure. All soldered and welded joints shall be uniform. Plated or coated surfaces shall be uniformly covered.

3.6 100-Percent Screening Tests.- All devices shall have been subjected to the 100-percent screening tests specified in the individual detail specification (see Figure 1 of this specification). All devices which fail to meet the screening requirements specified in the individual detail specification shall be removed from the lot and shall not be shipped to Hughes Aircraft Company.

3.7 Cleanliness.- The semiconductor devices shipped to Hughes Aircraft Company shall be delivered with all surfaces clean and free of oil, grease, and particle contamination.

3.8 Individual Detail Specification.- The detail requirements for the individual semiconductor devices shall be as specified in the individual detail specification. In the event of conflict between the provisions of this general specification and the individual detail specification, the latter shall govern.

4. QUALITY ASSURANCE PROVISIONS

4.1 Classification of Tests.- The inspection and testing of the semiconductor devices shall be classified as follows:

(a) Qualification tests. (See 4.2.)

(b) Acceptance tests. (See 4.3.)

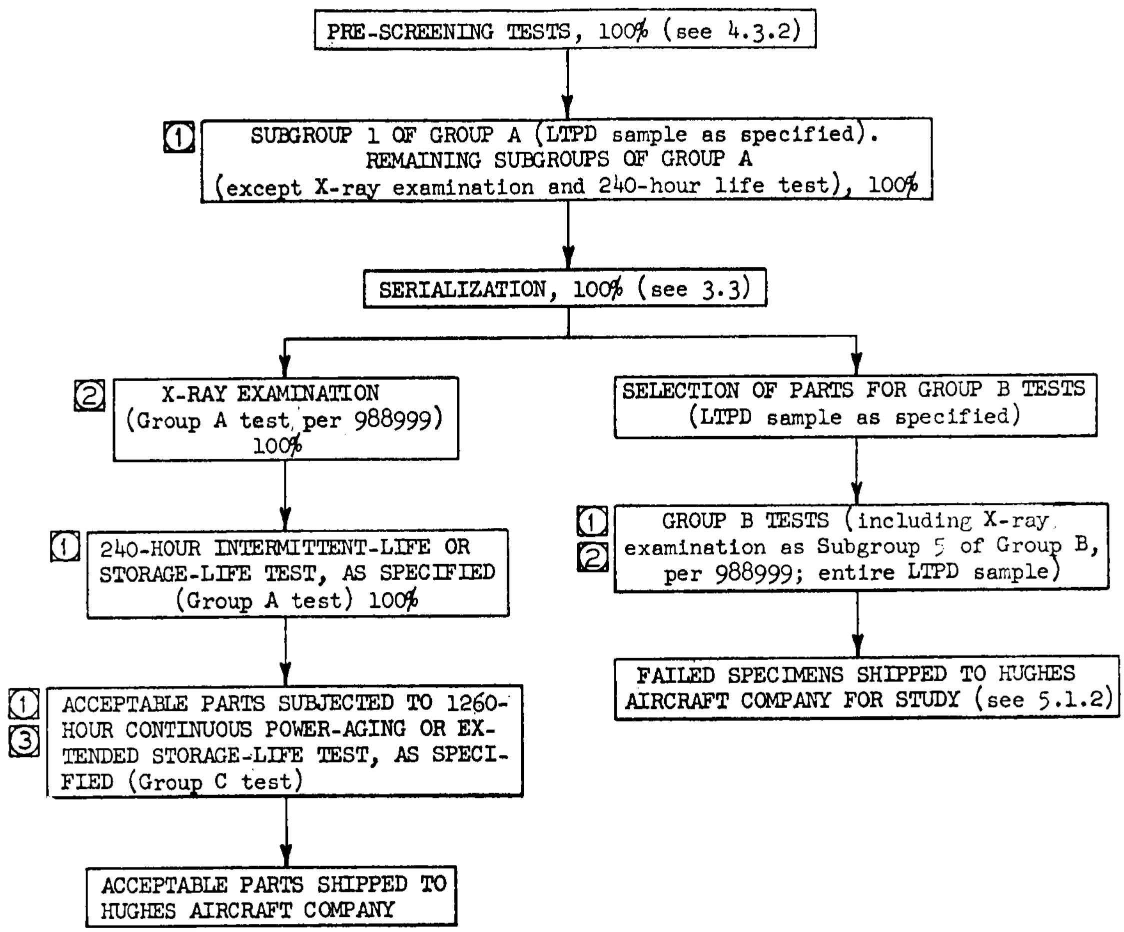
4.1.1 Additional Tests.- Nothing shall prevent the manufacturer from taking such additional samples and performing such additional tests as he may deem necessary or desirable to assure conformance to the requirements of this specification. Additional tests may be conducted by Hughes Aircraft Company to verify data submitted by the manufacturer.

4.2 Qualification Tests.- Hughes Aircraft Company is responsible for the performance of the specified qualification tests. These tests, which shall consist of all Group A and B tests specified in Tables II and III of the individual detail specification, will be conducted by, or at a laboratory designated by, Hughes Aircraft Company, to determine whether the devices meet the requirements of this specification.

4.2.1 Qualification Test Sample and Routine.- The total qualification test sample, consisting of 30 specimens which have not previously been subjected to a 240-hour intermittent-life or storage-life test by the manufacturer, shall be subjected to the Group A and B tests specified in Tables II and III of the individual detail specification. For purposes of qualification testing, the Group C tests of Table IV shall not apply, and the X-ray test shall be performed only at the conclusion of the Group B tests.

4.2.2 Post-Qualification-Test End Points.- The end-point tests specified in the individual detail specification shall be performed after the 240-hour intermittent-life or storage-life test of Group A, and after each qualification test specified in Subgroups 2 and 3 of Group B.

4.3 Acceptance Tests.- The manufacturer is responsible for performing all specified acceptance tests before the parts are shipped to Hughes Aircraft Company. The sequence of acceptance testing is shown in Figure 1. The Group A and C acceptance tests shall be performed as specified in Tables II and IV of the individual detail specification, on each part number ordered. The parts selected for the Group B acceptance tests shall come from the same homogeneous population (manufacturing lot) as that from which parts had been drawn for the Group A tests. The Group B tests may be performed on any part number listed in the part-number table. Tests within each subgroup shall be conducted in the order specified.



1 Variables data required.

2 Radiographs shipped to Hughes Aircraft Company.

3 Parts may be required for final shipment at any time after the beginning and prior to the end of the power-aging or storage-life test.

FIGURE 1

SEQUENCE OF ACCEPTANCE TESTING

4.3.1 Test Equipment and Facilities.- The manufacturer may use his own or any other laboratory facilities approved by Hughes Aircraft Company. The quality of the facilities and the accuracy of the equipment shall be sufficient to assure performance of the Group A, B, and C acceptance tests within the requirements specified.

4.3.2 Pre-Screening Acceptance Tests.- Before the test specified in Subgroup 1, Group A, of Table II of the individual detail specification is performed, the semiconductor devices shall be subjected to the tests described in 4.3.2.1 through 4.3.2.4, below. These tests may be carried out in any order, except that the centrifuge test shall be performed last.

4.3.2.1 Temperature Cycling.- The semiconductor devices shall be tested in accordance with Method 102 of MIL-STD-202. The test condition or the temperature extremes shall be as specified in the individual detail specification, and the test shall be extended to a minimum of 10 complete cycles.

4.3.2.2 Seal (Liquid Pressure).-

(To be completed)

4.3.2.3 Seal (Tracer Gas).- The devices shall be tested in accordance with Method 112, Test Condition C, of MIL-STD-202. The leakage-rate sensitivity shall be 10^{-8} atmospheric cubic centimeter per second. Any one of the five procedures specified may be used, at the option of the manufacturer.

4.3.2.4 Centrifugal Acceleration.- The semiconductor devices shall be tested in accordance with Method 2006 of MIL-STD-750, except that a centrifugal force of 20,000 G shall be applied along the Y_1 axis only.

4.3.3 Acceptance-Test Sample Selection

4.3.3.1 100-Percent Screening Tests.- All devices shall be subjected to the 100-percent screening tests specified in Groups A and C of the individual detail specification.

4.3.3.2 Sampling Tests.- The number of specimens selected for the remaining acceptance tests of Group A and all tests of Group B shall be that minimum sample size listed in Table I of this specification necessary to assure, with 90-percent confidence, the Lot Tolerance Percent Defective (LTPD) specified in Tables II and III of the individual detail specification.

TABLE I

MINIMUM SIZE OF SAMPLE TO BE TESTED TO ASSURE, WITH A 90-PERCENT CONFIDENCE, A LOT TOLERANCE PERCENT DEFECTIVE (LTPD) OR LIFE-TEST FAILURE RATE (λ) NO GREATER THAN THAT SPECIFIED

ACCEPTANCE NUMBER (a)	MAXIMUM LOT TOLERANCE PERCENT DEFECTIVE (LTPD) OR LIFE-TEST FAILURE RATE (λ) 4					
	15	10	7	5	3	2
(r = a + 1)	MINIMUM SAMPLE SIZES 5					
0	15 (0.34)	22 (0.23)	32 (0.16)	45 (0.11)	76 (0.07)	116 (0.04)
1	25 (1.4)	38 (0.94)	55 (0.65)	77 (0.46)	129 (0.28)	195 (0.18)
2	34 (2.24)	52 (1.6)	75 (1.1)	105 (0.78)	176 (0.47)	266 (0.31)
3	43 (3.2)	65 (2.1)	94 (1.5)	132 (1.0)	221 (0.62)	333 (0.41)
4	52 (3.9)	78 (2.6)	113 (1.8)	158 (1.3)	265 (0.75)	398 (0.50)
5	60 (4.4)	91 (2.9)	131 (2.0)	184 (1.4)	308 (0.85)	462 (0.57)
6	68 (4.9)	104 (3.2)	149 (2.2)	209 (1.6)	349 (0.94)	528 (0.62)
7	77 (5.3)	116 (3.5)	166 (2.4)	234 (1.7)	390 (1.0)	589 (0.67)
8	85 (5.6)	128 (3.7)	184 (2.6)	258 (1.8)	431 (1.1)	648 (0.72)
9	93 (6.0)	140 (3.9)	201 (2.7)	282 (1.9)	471 (1.2)	709 (0.77)
10	100 (6.3)	152 (4.1)	218 (2.9)	306 (2.0)	511 (1.2)	770 (0.80)

4 The life-test failure rate, lambda (λ), is defined as the LTPD per 1,000 hours.

5 The minimum quality (approximate AQL) required to accept, on the average, 19 of 20 lots is shown in parentheses for information only.

4.3.3.3 Small Lot Procurement.- If less than 100 units of any part listed in the part-number table are shipped against one purchase order, the acceptance tests for that lot shall be conducted as follows: All Group A and C tests shall be performed on a 100-percent inspection basis. All Group B tests shall be performed on a sample size of 10 specimens for each subgroup or, at the manufacturer's option, 10 specimens for all subgroups. No failures shall be allowed in the Group B acceptance tests. If a failure occurs during Group B inspection, the lot shall be rejected and permission shall be obtained from Hughes Aircraft Company before a new lot is subjected to acceptance testing.

4.3.4 Screening-Test Rejections.- Defectives found during the 100-percent screening tests (see 4.3.3.1 and 4.3.3.3) shall be eliminated from the lot.

4.3.5 Sampling-Test Procedure

4.3.5.1 Additional Samples.- After the test has started, an additional quantity of specimens may be added to the initial test sample, but these specimens may be added only once for any subgroup, and the added specimens must be subjected to all of the tests within the subgroup. The final sample size (initial and added specimens) shall determine the new acceptance number. The total defects of the initial and additional sample shall be additive and must comply with the specified LTPD.

4.3.5.2 Tightened Inspection.- Tightened inspection may be instituted on lots that have failed acceptance inspection by testing to an LTPD equal to, or less than, half of the specified LTPD. A lot which fails tightened inspection shall not be retested and shall not be shipped to Hughes Aircraft Company.

4.3.5.3 Disposition of Sampling-Test Specimens.- Specimens which have been subjected to the destructive tests of Group B shall not be included with the acceptable devices, but shall be shipped to Hughes Aircraft Company in separate packages, as specified in 5.1.2 and 5.2.2.

4.3.6 Post-Acceptance-Test End Points.- The designated acceptance-test end points shall be measured after the 240-hour intermittent-life or storage-life test specified in Group A, and after the completion of all tests in each of Subgroups 2 and 3 of Group B.

4.3.7 Certification.- The supplier shall certify with each shipment that:

(a) The acceptance tests specified in 4.3 have been performed.

(b) The devices meet all of the applicable acceptance requirements.

(c) The shipment does not contain devices from a production lot that has failed tightened inspection (see 4.3.5.2).

Any deviation from this certification requirement shall be fully explained in writing.

4.3.8 Data Submittal.- The manufacturer shall forward to Hughes Aircraft Company the data specified in paragraphs 4.3.8.1 through 4.3.8.4. The records shall be certified by a responsible company official and shall be sent along with each shipment of semiconductor devices. Acceptance of the shipment of devices shall be contingent upon the acceptance by Hughes Aircraft Company of the data submitted.

4.3.8.1 Test Records.- Complete records of all the acceptance tests performed by the manufacturer or his designated agency shall be submitted. The data supplied shall be variables data, unless specifically waived by Hughes Aircraft Company. The information shall be recorded in a manner which will facilitate the following of the behavior of each test specimen from the beginning to the end of each test, and shall include explanatory comments which will aid in the evaluation of any unusual or abnormal events that may have occurred during the tests. The data format shall include, but shall not be limited to, the following items:

(a) The Hughes Aircraft Company purchase-order number.

(b) The Hughes Aircraft Company specification number and revision letter.

(c) The manufacturer's part number.

(d) The manufacturer's lot number.

(e) The manufacturer's test procedure, or reference thereto if previously submitted for correlation.

(f) The limits specified for each characteristic measured, as indicated in the Hughes Aircraft Company specification.

The data shall be identified as follows:

(g) The data shall be keyed to, or referenced to, the paragraph numbers of the Hughes Aircraft Company specification, or the method number of MIL-STD-750.

(h) Failures shall be identified as to mode of failure.

(i) All data which indicates a discrepant condition shall be circled.

4.3.8.2 Test-Equipment Record.- A detailed report shall be submitted with the initial shipment of devices which lists the equipment used to obtain the test results. Each piece of equipment shall be identified by means of the manufacturer's name, the model number, and the calibration date. This report need not be resubmitted with subsequent shipments unless the test equipment employed differs with each lot tested.

4.3.8.3 X-Ray Test Records.- The radiographs obtained during the X-ray tests shall be submitted.

4.3.8.4 Lead Material.- A statement describing the composition of the leads, the composition and thickness of the base material, and the type of plating or finish applied to the base material shall be submitted.

4.3.8.5 Disposition of Records.- At least three copies of the test data and the test-equipment report shall be sent to the receiving activity of Hughes Aircraft Company. Two copies shall be enclosed in a separate envelope which shall be marked as follows: Attention, Components Department, M.S. D-147, Hughes Aircraft Company, Code RA-1.

4.4 Methods of Examination and Test

4.4.1 Standard Test Conditions.- Unless otherwise specified, all tests and measurements shall be performed with no direct draft on the devices and under the following ambient conditions:

Temperature ______ 25° ±3° C

Pressure ______ 30 ±2 inches of mercury

Relative Humidity ______ 60 percent (maximum)

4.4.2 Alternate Test Conditions.- Measurements and tests may be performed under conditions other than those stated in 4.4.1 if the manufacturer demonstrates the validity of the correlated data and obtains written approval from Hughes Aircraft Company.

4.4.3 MIL-STD-750 Tests.- The devices shall be subjected to the MIL-STD-750 tests specified in the individual detail specification. The following exceptions and modifications shall apply when the test is specified:

(a) Reduced Barometric Pressure.- In Method 1001 of MIL-STD-750, the devices shall be electrically insulated from the test chamber and shall not be furnished with heat sinks. An oscilloscope shall be used to monitor the waveform of the parameter specified, and to observe any variations which may indicate deterioration of the device under test.

(b) Moisture Resistance.- In Method 1021 of MIL-STD-750, subparagraph 2(a) shall not apply.

(c) Continuous Power Aging.- In Method 1026 of MIL-STD-750, the operating time shall be 1260 ±12 hours. The test conditions shall be as specified in the individual detail specification. The specified end points shall be measured at 0 hours, 500 hours, and at the completion of the test.

(d) High-Temperature Storage Life.- In Method 1031 of MIL-STD-750, the operating time shall be 240 hours or 1260 ±12 hours, as specified see (1) and (2), below. The test conditions shall be as specified in the individual detail specification.

(1) 240-Hour Storage Life.- All devices shall undergo the 240-hour storage-life test, when specified. At the conclusion of the test, the devices shall be allowed to stabilize at room temperature before being subjected to the end-point tests specified. The lot shall be acceptable if not more than 5 percent of the lot fails the test. Shipped devices shall be capable of meeting all Group A requirements.

(2) Extended Storage Life.- In the 1260-hour storage-life test, the specified end points shall be measured at 0 hours, 500 hours, and at the completion of the test. The devices shall be allowed to stabilize at room temperature before the end points are measured.

(e) Intermittent Operation Life.- In Method 1036 of MIL-STD-750, the duration of the test shall be 240 hours. All devices shall undergo this test, when specified. The test voltage or current specified in the individual detail specification shall be applied in cycles, each cycle consisting of a 15-minute on period, followed by a 5-minute off period. After a total of 240 hours, the test voltage shall be removed, and the devices shall be allowed to stabilize at room temperature before being subjected to the end-point tests specified. The lot shall be acceptable if not more than 5 percent of the lot fails the test. Shipped devices shall be capable of meeting all Group A requirements.

(f) Shock.- In Method 2016 of MIL-STD-750, no test voltages shall be applied. Each device shall be subjected to five 1500 G shocks in each direction, along each of three mutually perpendicular axes (total of 30 shocks). The duration of each shock shall be approximately 0.5 millisecond.

(g) Terminal Strength.- In Method 2046 of MIL-STD-750, no test voltage shall be applied. The peak acceleration shall be not less than 20 G.

(i) Visual and Mechanical Examination.- In Method 2071 of MIL-STD-750, all devices shall be internally examined under a minimum of 15 X magnification prior to final assembly and seal. Particular attention shall be given to observing foreign particles, cracks, holes, blisters, or other imperfections within the device. The internal structure shall be inspected for evidence or misalignment of mechanical distortion. After final assembly, the devices shall be externally examined under a minimum of 10 X magnification. Soldered or welded joints shall be examined to assure uniformity. Coated or plated surfaces shall be examined for evidence of uncovered areas. (See 3.5.)

4.4.4 Supplementary Tests

4.4.4.1 X-Ray Inspection.- All semiconductor devices shall be radiographically examined as described in Hughes Aircraft Company Document 988999.

4.4.4.2 Additional Tests.- The semiconductor devices shall be subjected to additional tests when so specified in the individual detail specification.

5. PREPARATION FOR DELIVERY

5.1 Packaging

5.1.1 Acceptable Parts.- All acceptable parts shipped to Hughes Aircraft Company shall be packaged individually or in groups of not more than 10 units. The containers shall be sealed and shall be provided with one or more transparent surfaces through which a parts count can be made without removing the contents. Each package shall contain only devices with the same part number. The large external shipping container, which may contain unit packages with different part numbers, shall be constructed so as to ensure safe and undamaged delivery of the parts. Unit packages which are received in a broken or injured condition will be unacceptable and will be returned to the supplier.

5.1.2 Failed Specimens.- Parts submitted for purposes other than for use (such as specimens that have failed the Group B tests and are being shipped to Hughes Aircraft Company for further study) shall be packaged as specified in 5.1.1, but with the additional marking specified in 5.2.2.

5.2 Marking of Packages

5.2.1 Acceptable Parts.- The unit packages and the large external shipping container shall be clearly marked with the manufacturer's name and/or trademark, the manufacturer's part number, the lot identification or date code, and with the Hughes number enclosed in parentheses.

5.2.2 Failed Specimens.- Packages in which failed specimens (see 5.1.2) are shipped shall be marked as specified in 5.2.1, and with the following additional marking: "TESTED SPECIMENS - DO NOT USE."

6. NOTES

6.1 Definitions, Abbreviations, and Symbols.- The terms used in this general specification are defined in Appendix A, and the abbreviations and symbols are defined in Appendix B of MIL-S-19500. Additional symbols, if any, are defined in the individual detail specification.

6.2 Approval of Manufacturer

6.2.1 Performance Ability.- The manufacturer shall have demonstrated his ability to supply uniform, reliable products as specified below.

6.2.2 Approval to NASA Quality Publication NPC 200-3.- Manufacturers supplying to this specification shall be inspected and approved by a representative of Hughes Aircraft Company for compliance to the provisions specified in NASA Quality Publication NPC 200-3. When a conditional approval is granted, the manufacturer must take the corrective action specified in the time allotted. At any time prior to the shipment of the devices, a representative of Hughes Aircraft Company may reinspect the manufacturer's facility to assure continued compliance to the NASA publication. Where serious discrepancies are found, no further processing of the order will be allowed until such discrepancies are corrected.

6.3 Off-Premises Qualification Testing.- When qualification testing is performed at facilities other than those of Hughes Aircraft Company, the following requirements shall apply.

6.3.1 Preparation for Shipment.- Tested specimens shall be packaged in the condition in which they emerge upon conclusion of the final test, and in accordance with 5.1.2.

6.3.2 Data Submittal.- Data shall be submitted in accordance with 4.3.8, except that references to "acceptance tests performed by the manufacturer" shall be interpreted as "qualification tests performed by the off-premises facility."

X-Ray Inspection

The general specification references on X-ray specification, Hughes X988999, which has been prepared expressly for Advanced Syncom. It is a cross-section of requirements and practices common in the industry and has been discussed with all the suppliers. It will be involved in procurement of all transistors, most diodes, and on passive devices where applicable in Advanced Syncom.

1. SCOPE

1.1 This specification covers X-ray inspection requirements and nondestructive test methods for semiconductor devices intended for use in high-reliability systems. This specification supplements the Hughes Aircraft Company individual standard for the semiconductor device.

1.2 The radiographic techniques specified herein are designed to reveal discrepancies in the fabrication of the devices, such as misaligned crystals, displaced getter rings, inadequate clearances, voids in encapsulating or potting compounds, inhomogeneities in materials, presence of foreign or extraneous matter, tear-drop deposits, etc.

2. APPLICABLE DOCUMENTS

2.1 The following documents, of the latest issue in effect, shall apply to this specification to the extent specified herein:

MIL-X-6141	X-ray Laboratories, Procedure for the Certification of
MIL-I-6865	Inspection, Radiographic

3. REQUIREMENTS

3.1 Certification and Surveillance of X-ray Test Facility

3.1.1 Certification.- The X-ray test facility performing radiography in conjunction with the inspection of semiconductor devices, as specified herein, shall be certified by at least one of the military services or by the National Aeronautics and Space Administration (NASA), in accordance with MIL-X-6141. Interim approval may be granted by a representative of Hughes Aircraft Company, pending formal survey and certification.

3.1.2 Surveillance.- The X-ray test facility may be surveyed and inspected without prior notification at any time by Hughes Aircraft Company, at its discretion.

3.1.3 Revocation of Certification.- In the event that serious deficiencies or discrepancies are discovered which affect the requirements or the performance of the tests specified herein, the X-ray test facility will be disapproved for further testing, until such time as the discrepancies are corrected by the test facility to the satisfaction of Hughes Aircraft Company.

3.1.4 Notification of Status.- The X-ray test facility will be notified by Hughes Aircraft Company, in writing, of approval, disapproval, or reinstatement in accordance with MIL-X-6141.

3.2 Deviations.- Any deviations from the requirements or test procedures stated in this specification shall be explained in detail, in writing, by the test facility, and shall be approved by Hughes Aircraft Company before being implemented.

3.3 Identification

3.3.1 Marking of Radiographic Film.- Each radiograph shall be clearly and permanently marked with the certification number and name and/or trademark of the test facility, the semiconductor-device manufacturer's name and/or trademark, the manufacturer's part number, the lot number, the view number, the serial number or X-ray control number, and with the Hughes number of the device. Suitable means shall be used to identify individual devices on the radiographic record.

3.3.2 Marking of Acceptable Devices.- Devices which have met the requirements of this specification shall be permanently marked with a white dot of fungus-resistant paint or ink, and either the serial number or X-ray control number. Marking shall be positioned so as not to obscure the other marking on the devices.

3.4 Classification of Rejects or Failures.- Following examination and inspection of the radiographs, the devices shall be rejected for the presence of any of the following conditions:

(a) Inadequate Clearance.- The clearance (minimum distance) between electrical connections on the post and header (case), and between the whisker and header (case), shall exceed the diameter of the support post. (See Figure 1.) In devices with a vertical crystal mount, the minimum clearance between the crystal mount and the header (case) shall be 0.002 inch.

(b) Misaligned Crystals.- Crystals shall not be tilted more than 15 degrees when measured from the normal to the main axis, or offset more than one-third of their contact surface with the base. Crystals shall not be fused to any wall or surface. (Touching is permissible. See Figure 2.)

(c) Extraneous Matter.- Loose wires, solder balls, or attached extraneous matter shall not exceed 0.001 inch in the major diameter or dimension. (See Figure 3.)

(d) Tear-Drop Deposits.- Welding substances, solder, gold paste, or other bonding and conducting materials shall not form tear-drop deposits at any re-entrant surface. (See Figure 4.)

(e) Physical Damage.- Crystals, terminals, mountings, or whisker wires shall not exhibit signs of undercutting, cracking, fracture, splitting, chipping, or other forms of physical or mechanical damage. Whisker wires shall not be doubled over or twisted, or show signs indicating compression during fabrication or assembly.

(f) Supernumeraries.- There shall be no presence of supernumeraries, such as two whiskers in a diode.

3.4.1 Acceptable Conditions.- Devices shall not be rejected for the presence of any of the following conditions:

(a) Material entrapped within the recessed ends of the glass housing and the outside coat of paint.

(b) Burned edges, molten-metal build-up, or deposits existing at the supporting terminations, which were produced by induction melting when such conditions are inherent with this process.

4. QUALITY ASSURANCE PROVISIONS

4.1 Test Sample and Routine.- Devices to be radiographed shall be selected from those previously subjected to the acceptance tests specified in the applicable Hughes Aircraft Company specification. Each lot shall be identified by a film number system which shall allow identification of the individual units.

4.2 X-ray Inspection and Test Methods.- The devices shall be subjected to the inspection and tests specified in MIL-I-6865, with the following modifications and additions:

(a) Pre-Treatment of Devices.- The devices shall not be subjected to ultrasonic cleaning immediately prior to X-ray inspection.

(b) Resolution or Sensitivity of X-ray Equipment.- Equipment used in the radiography of the devices shall be capable of detecting a particle size of 0.001 inch when measured in the major dimension, or shall be capable of producing 2 percent sensitivity (X-ray quality level II per MIL-I-6865). The final image shall be examined with suitable viewing equipment which may include magnification to determine the effects specified for failure in 3.4.

(c) Area to be X-rayed.- Two views, perpendicular to each other, shall be taken of each device, normal to the main axis. Images shall not be projected on the film nor be "ellipsed" by more than ±5 degrees from the normal to the central ray.

(d) X-ray Exposure Levels.- Unless otherwise specified, the devices shall be radiographed with the following exposure factors and sensitivity levels:

(1) Effective Voltage range from 50 to 150 kilovolts peak.

(2) Focal spot of 2.5 millimeters or less.

(3) Film focal distance of 48 inches minimum.

(4) Metallic screen (lead) or filter of 0.005 inch thickness for the table window.

Exposure time shall be kept at a minimum to achieve the required image definition. The milliamperage, source-to-film distance, and time settings shall be selected to obtain maximum radiographic quality.

(e) Selection of Radiographic Film.- X-ray production film shall be selected from the following types of high-contrast, fine-grained safety film or suitable equivalent:

(1) Eastman Kodak "M" - single emulsion

(2) Ansco FPC 237

(3) Dupont 510 - single or double emulsion

(4) Geveart D-2 - single or double emulsion

(f) Processing of X-ray Film.- For maximum contrast, the exposed X-ray film shall be processed with high-contrast developers in accordance with the manufacturer's recommendations accompanying the process solution.

(g) Handling of Devices During X-ray.- During the X-ray procedure, the devices shall not be dropped, and shall not be exposed to an overdose of radiation. The leads shall not be bent.

(h) Auxiliary Test Equipment.- Additional equipment used in the radiography of semiconductor devices shall include the following:

(1) Lead-lined table top or support

(2) Lead foil or letters and/or numbers for film identification

(3) Fixtures for mounting the devices during radiography, which contain no supports between the device and the film. Adhesives, when used, shall be applied only to the unpainted surface of the device.

(i) Inspection and Examination of Radiographs.- Initial inspection of the radiographs shall be performed with suitable viewing equipment of at least 10-power magnification. Detailed inspection shall be performed with viewing equipment of at least 20-power magnification.

4.3 Defects

4.3.1 Examination of Defects.- Following the X-ray test of the devices, the radiographs shall be examined for evidence of discontinuities which may weaken or decrease the durability of the device, or evidence of defects exceeding the permissible limits of the device as specified in the applicable Hughes Aircraft Company specification and in 3.4 of this specification.

4.3.2 Identification of Defects.- Rejects or failures shall be clearly identified by encircling the defective portion of the image on the radiograph.

4.3.3 Calibration Standard.- The test facility shall use a slide or calibrated standard with built-in defects of various thicknesses, for reference purposes in determining failures or rejections.

4.3.4 Disposition of Rejects.- Rejects shall be removed from the X-ray lot and shall be reported to Hughes Aircraft Company.

4.4 Failure Analysis and Report.- When the X-ray tests are performed as acceptance tests, the manufacturer shall prepare a failure analysis on all failures and rejects, and shall forward a written report to Hughes Aircraft Company which contains the following information:

(a) Type of failure or defect noted

(b) Cause and effect of failure

(c) Corrective action taken

4.5 Certification of Tests.- The test facility shall certify that:

(a) The X-ray tests have been performed in accordance with this specification.

(b) The radiographs have been properly inspected.

(c) The devices and radiographs have been properly marked and classified.

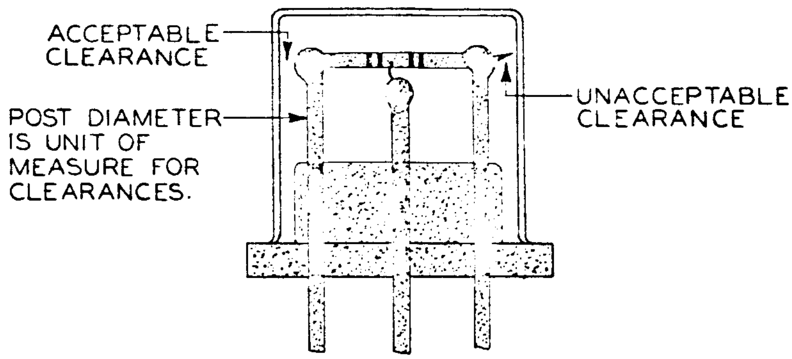
Any deviation from this certification instruction shall be explained in detail in writing.

4.6 Inspection Reports.- Unless otherwise specified, the test facility shall furnish inspection reports, giving the results of the X-ray inspection required, and signed by an authorized representative of the test facility. The report shall list the Hughes number, the date of test, the serial number of the test, the rated condition of the part, the voltage and current used in the X-ray process, the approximate angle between the central beam of radiation and the film, the screens and filter used, and the method of mounting the devices.

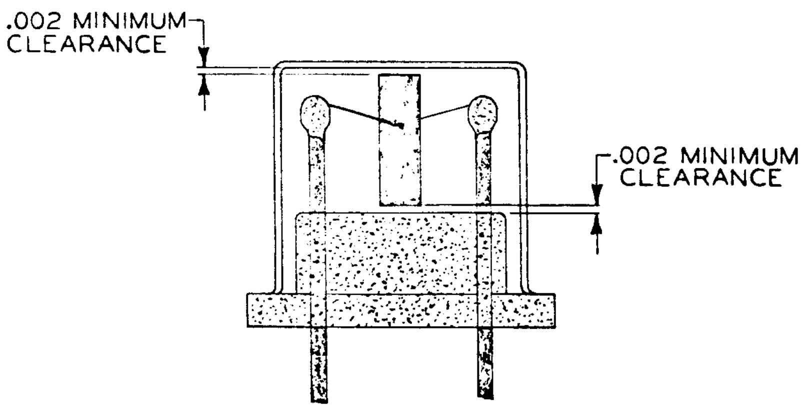
4.7 Data Submittal.- The data accumulated in performing the tests specified herein, including radiographs and reports, shall be forwarded to Hughes Aircraft Company along with the shipment of devices.

DO NOT SCALE

LIMITS UNLESS OTHERWISE SPECIFIED: .XXX ± .XX ± X° ±



A



B

FIGURE 1

INADEQUATE CLEARANCE

SPECIFICATION CONTROL DOCUMENT

APPROVED / ISSUE DATE	HUGHES AIRCRAFT COMPANY CULVER CITY, CALIFORNIA	STANDARD	REVISION
PROCUREMENT SPECIFICATION NONE	X-RAY INSPECTION PROCEDURES FOR SEMICONDUCTOR DEVICES	X988999 PAGE 6 OF 8	

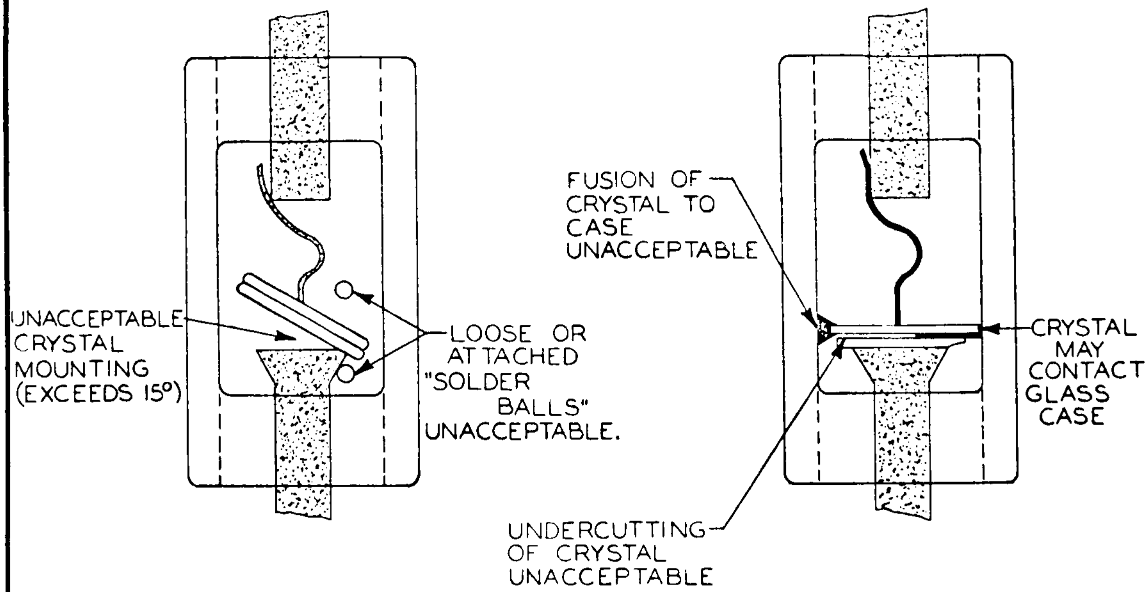


FIGURE 2

MISALIGNED CRYSTALS

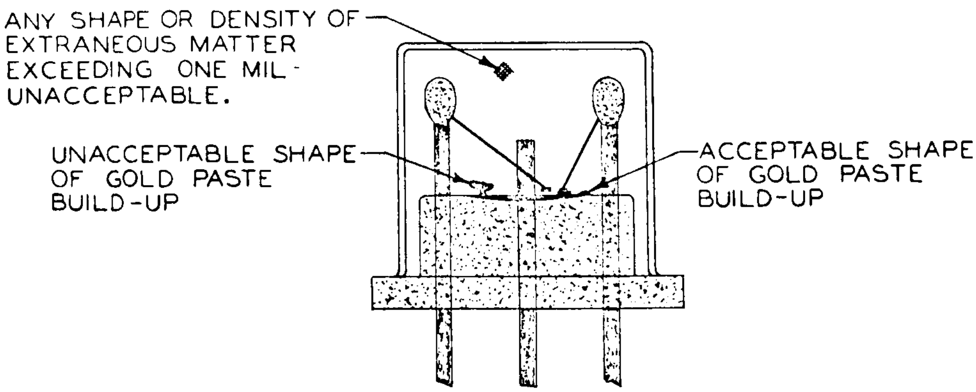


FIGURE 3

EXTRANEOUS MATTER

DO NOT SCALE

LIMITS UNLESS OTHERWISE SPECIFIED: .XXX = ± .XX = ± X° = ±

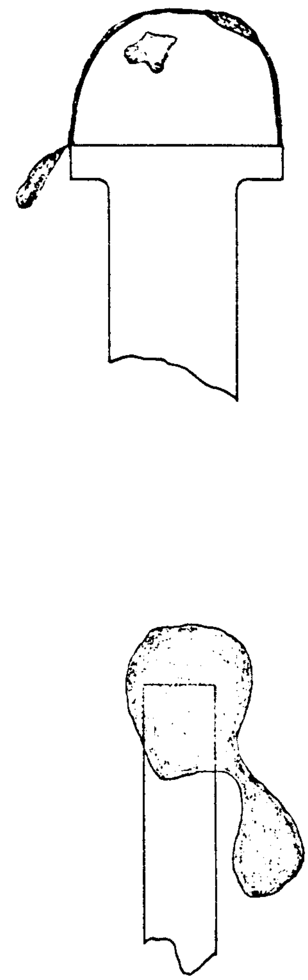


FIGURE 4

UNACCEPTABLE SOLDER AND GOLD PASTE DEPOSIT FORMATIONS
TEAR-DROP DEPOSITS

SPECIFICATION CONTROL DOCUMENT

APPROVED	ISSUE DATE	HUGHES AIRCRAFT COMPANY CULVER CITY, CALIFORNIA	STANDARD	REVISE
PROCUREMENT SPECIFICATION NONE		X-RAY INSPECTION PROCEDURES FOR SEMICONDUCTOR DEVICES	X988999 PAGE 8 OF 8	

Passive Devices

Nine resistor types and nine capacitor types are described in the basic specifications, like in the case of semiconductors. An addendum has been prepared for each specification applying Advanced Syncom requirements for serial numbering, power aging, noise, and X-ray tests (where applicable). Two specifications are presented as being typical and exemplary of the above for a resistor and a capacitor.

1. SCOPE

1.1 Scope.- This specification covers fixed, film, accurate, hermetically sealed resistors that possess a high degree of stability, with respect to time under severe environmental conditions. It is designed to define a product that represents the most advanced state of the art, and to define a product which will operate reliably in space and lunar environments.

2. APPLICABLE DOCUMENTS

2.1 Applicable Documents.- The following documents, of the issue in effect on the date of invitation for bids, form a part of this specification to the extent specified herein.

MIL-R-10509	Resistors, Fixed, Film (high stability), General Specification for
MIL-Q-9858	Quality Control System Requirement

3. REQUIREMENTS

3.1 MIL-R-10509 Requirements.- The requirements for resistors listed for Characteristic B in Specification MIL-R-10509 shall apply to these resistors with the following exceptions and modifications.

3.1.1 Detail Requirements.- The dimensional and electrical characteristics listed in the detail specifications are modified to the extent indicated in paragraph 3.4.

3.1.2 Power Rating.- These resistors have a power rating based on continuous full-load operation at an ambient temperature of 70° C. (See Figure 2.)

3.1.3 Temperature Coefficient.- The temperature coefficient of resistance is specified in Figure 1.

3.1.4 Design and Construction.- These resistors shall consist essentially of a resistive film of pure crystalline carbon, pyrolytically deposited upon the surface of a circular, cylindrical ceramic core. This unit shall be hermetically housed within a glass envelope.

3.1.5 Workmanship.- The surface of these resistors shall be free of oils and greases, including impregnants and anti-wetting agents.

3.1.6 Terminals.- The axial leads shall be composed of "A" nickel.

3.1.7 Solderability.- All references to solderability of terminals shall be ignored wherever it appears in the above referenced specification.

3.1.8 Marking.- Resistors shall be marked legibly and permanently with the resistance value, resistance tolerance and the manufacturer's identification.

6871
4-15-6

SPECIFICATION CONTROL DOCUMENT

APPROVED	15 MAR 62 ISSUE DATE	HUGHES AIRCRAFT COMPANY CULVER CITY CALIFORNIA	
		RESISTOR, FIXED, FILM - DEPOSITED CARBON	PAGE

3.2 MIL-Q-9858 Requirements.- All applicable requirements of Specification MIL-Q-9858 shall constitute the minimum requirements for resistors manufactured to this specification.

3.3 Supplementary Requirements

3.3.1 Fresh Product.- These resistors shall be of recent production and shall be supplied by the manufacturer only.

3.3.2 Hard Vacuum Operation.- When resistors are tested as specified in 4.5.2.1, there shall be no evidence of mechanical damage, no degradation of insulation resistance, and no change in resistance in excess of the initial tolerance figure.

3.3.3 Thermal Shock.- When resistors are tested as specified in paragraph 4.5.2.2, there shall be no mechanical damage or change in resistance exceeding 0.50 percent.

3.3.4 Sterilization Procedure.- When resistors are conditioned as described in 4.5.2.3, there shall be no mechanical degradation or change in resistance exceeding 0.10 percent.

3.4 Detail Requirements.- Detail Requirements applicable to all resistors covered in this specification are listed in Figure 1 and the part number table. In the event of conflict between the general requirements of this specification and the detail requirements, the latter shall govern.

3.4.1 Case Dimensions and Parameters.- The dimensions and parameters are delineated in Figure 1.

3.4.2 Part Number Table.- The resistance values enumerated in the part number table are identical with the standard resistance values listed in MIL-R-10509D for one percent resistors. Resistance values other than those listed are not available under this specification.

4. QUALITY ASSURANCE PROVISIONS

4.1 Classification of Inspection

(a) Qualification Tests (See 4.2)

(b) Acceptance Tests (See 4.3)

(c) 100 Percent Conditioning and Screening Tests (See 4.4)

4.2 Qualification Tests.- The manufacturer is responsible for the performance of qualification tests.

4.2.1 MIL-R-10509 Qualification Tests.- These resistors shall be subjected, as a minimum requirement, to qualification tests of the extent and severity described in Table V of MIL-R-10509.

4.2.1.1 Failures.- No failures are permitted in these tests.

4.2.2 Supplementary Qualification Tests.- The supplementary tests shall be performed by Hughes Aircraft Company.

4.2.2.1 Test Sample and Routine.- Ten resistors of maximum and critical value shall be subjected, in sequence, to the tests of Table I.

TABLE I

Test	Requirement	Procedure
Sterilization Procedure	3.2.4	4.3.2.3
Thermal Shock	3.2.3	4.3.2.2
Hard Vacuum Operation	3.2.2	4.3.2.1

4.2.2.2 Failures.- No failures are permitted in these tests.

4.3 Acceptance Tests.- The manufacturer is responsible for the performance of all specified acceptance tests.

4.3.1 MIL-R-10509 Acceptance Tests.- The Groups A, B, and C acceptance inspection tests and inspection procedures of paragraph 4.5 of MIL-R-10509 are applicable to this specification, with the exception of the solderability tests.

4.4 100 Percent Conditioning and Screening Tests.- The manufacturer is responsible for performance of the specified conditioning and screening tests.

4.4.1 Tests.- All resistors shipped to this specification shall be subjected to the following tests. All rejected resistors shall be removed from the shipment.

Test	Paragraph
Initial Resistance Measurement	4.5.3.1
Seal Test	4.5.3.2
Power Conditioning	4.5.3.3
Noise Measurement	4.5.3.4
Final Resistance Measurement	4.5.3.1

4.4.2 Data Submittal.- Two copies of the data required in paragraph 4.5.3.5 below shall be submitted with the shipment of resistors. It shall be contained within a sealed envelope and addressed to "Components Department, Culver City."

4.5 Methods of Examination and Test

4.5.1 MIL-R-10509 Test Procedures.- These resistors shall be subjected to tests at least of duration and severity as indicated in MIL-R-10509 (Characteristic B).

4.5.2 Supplementary Test Procedures.- The applicable test procedures of MIL-R-10509 shall be employed where no procedures are described.

4.5.2.1 Hard Vacuum Operation.- The resistance and insulation resistance shall be measured and the Dielectric Strength test shall be performed. The resistors shall then be mounted by their leads with their cases adhered by epoxy to an aluminum plate of 3 x 1 x .03 inch. A vacuum of 10^{-8} millimeters of mercury shall be effected and a continuous direct current voltage, which will produce rated power dissipation, shall be impressed across the resistors. This test shall be performed with the walls of the test chamber held at 70°C for a duration of 500 hours. Upon completion of test, the above listed measurements shall be repeated.

4.5.2.2 Thermal Shock.- These resistors shall be subjected to five cycles of tests. Each cycle shall consist of the following routine. The resistors, while at room temperature, shall be quickly immersed into liquid nitrogen. After ten minutes of immersion, the resistors shall be removed, and within one minute, shall be placed in a temperature cabinet maintained at 125° C ±3 percent. After ten minutes of exposure, the resistors shall be removed and exposed to room ambient temperature for five minutes. Upon completion of test, the resistance and insulation resistance shall be measured and the dielectric strength test shall be performed.

4.5.2.3 Sterilization Procedure

4.5.2.3.1 High Temperature.- These resistors shall be subjected to two 36-hour periods of exposure to a temperature of 125° C.

4.5.2.3.2 Chemical.- These resistors shall be subjected to an atmosphere consisting of a mixture of 12 percent ethylene oxide and 88 percent trichlorofluoromethane (Freon 12) by weight at a temperature of 38° ±2° C for a period of 24 hours. Upon completion of test, the resistance, insulation resistance, and dielectric strength tests shall be performed.

4.5.3 100 Percent Conditioning and Screening Test Procedures.

4.5.3.1 Initial Resistance Measurement.- The resistors shall be measured employing appropriate and technically sound techniques. All resistors with values exceeding the tolerance limits shall be rejected.

4.5.3.2 Seal Test.- The resistors shall be completely immersed in a dye preparation composed of approximately 5 grams of ZL-5 penetrant dye in one gallon of deionized water. The container with the resistors shall be transferred to a pressure chamber which shall be evacuated to a minimum pressure of 25 in. Hg for 30 minutes. The pressure in the chamber shall then be increased to 60 lbs. per square inch and held for 30 minutes. The resistors shall then be removed and rinsed with deionized water.

All resistors shall be removed which indicate dye penetration under a flourescent light of 3500 to 4000 Angstrom units wavelength.

4.5.3.3 Power Conditioning.- The resistors shall be mounted by the leads with their cases suspended. Twice rated power(250 volts maximum)shall be applied continuously for 240 ±4 hours. All resistors with a resistance change exceeding 0.4 percent shall be removed. If the rejection rate exceeds 3 percent, the entire lot shall be rejected.

All resistors which exceed the one percent tolerance shall also be removed, however, these resistors shall not be included in calculating the rejection percentage unless they have also deviated in excess of 0.4 percent as a result of test.

4.5.3.4 Noise Measurement.- The noise index for each resistor, in decibels, shall be measured with a standard resistor-noise test set, such as a Quan-Tech Laboratories model 315, or equivalent. Testing shall be conducted in accordance with Method 308 of MIL-STD-202. Resistors with a noise index in excess of the value shown in Figure 3 shall not be shipped.

4.5.3.5 Conditioning and Screening Test Data.- The following information shall be submitted with each shipment of resistors:

1. Initial and Final Resistance Measurements
2. A record of leak test failures

5. PREPARATION FOR DELIVERY

5.1 Packaging.- The resistors shall be mounted on a supporting structure which can easily be removed and replaced within the shipping container. The resistors shall be arranged in the form of a strip of ten resistors and shall be restrained from mutual contact. The leads shall be accessible for testing purposes without removing the resistors from the structure. The structure shall be of such design as to permit easy removal of the individual resistor from the strip. Each individual resistor shall be identified on the strip with a unique designation.

6. NOTES

6.1 Mounting.- Under conditions of severe shock or vibration, or a combination of both, these resistors should be mounted in such a fashion that the case of the resistor is restrained from movement with respect to the mounting base.

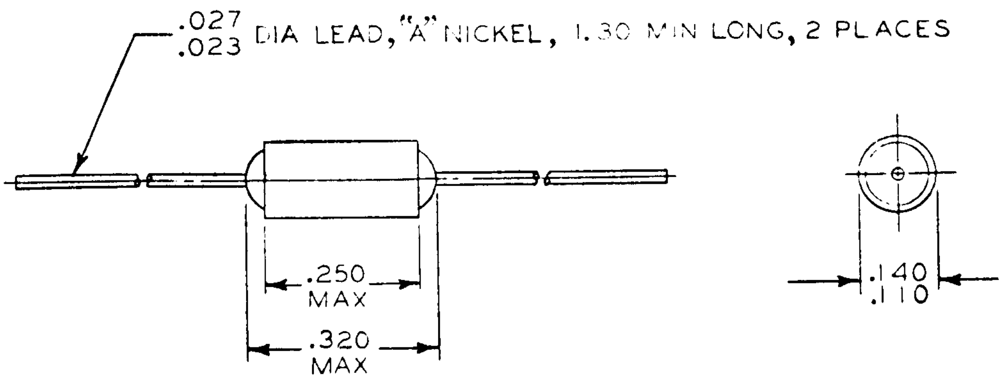
6.2 Power Derating.- When resistors are employed in ambient temperatures exceeding the rated temperature specified, the power input must be reduced in accordance with Figure 2.

6.3 Maximum Voltage.- The maximum continuous working voltage specified should not be exceeded regardless of the theoretically calculated rated voltage based on power.

6.4 Weight.- The approximate weight of each of these resistors is 0.35 gram.

DO NOT SCALE

LIMITS UNLESS OTHERWISE SPECIFIED: .XXX = ± .XX = ± X° = ±



SCHEMATIC SYMBOL

Detail Requirements

1.	Resistance Range Available	10.0 ohms to 100K
2.	Resistance Tolerance	±1.0%
3.	Power Rating (See Figure 2)	0.125 W at 70° C 0 W at 150° C
4.	Maximum Continuous Working Voltage	250 V
5.	Dielectric Strength	750 V
6.	Temperature Coefficient	- 180 to - 450 PPM/°C (B)

FIGURE 1

SPECIFICATION CONTROL DOCUMENT

APPROVED	ISSUE DATE	HUGHES AIRCRAFT COMPANY CULVER CITY, CALIFORNIA	STANDARD 988610
PROCUREMENT SPECIFICATION NONE		RESISTOR, FIXED, FILM,-- DEPOSITED CARBON	PAGE 6 OF 11

(B) (A) REVISED

DO NOT SCALE

LIMITS UNLESS OTHERWISE SPECIFIED: .XXX ± .XX ± X° ±

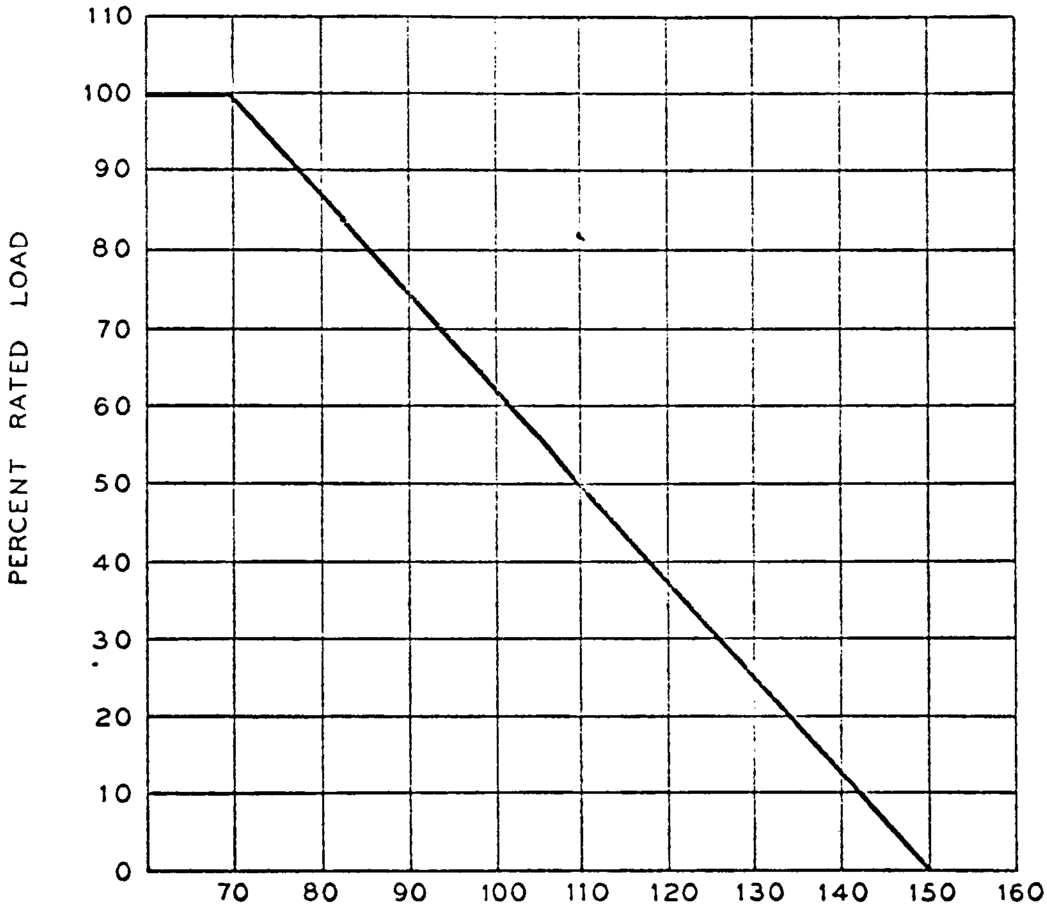


FIGURE 2

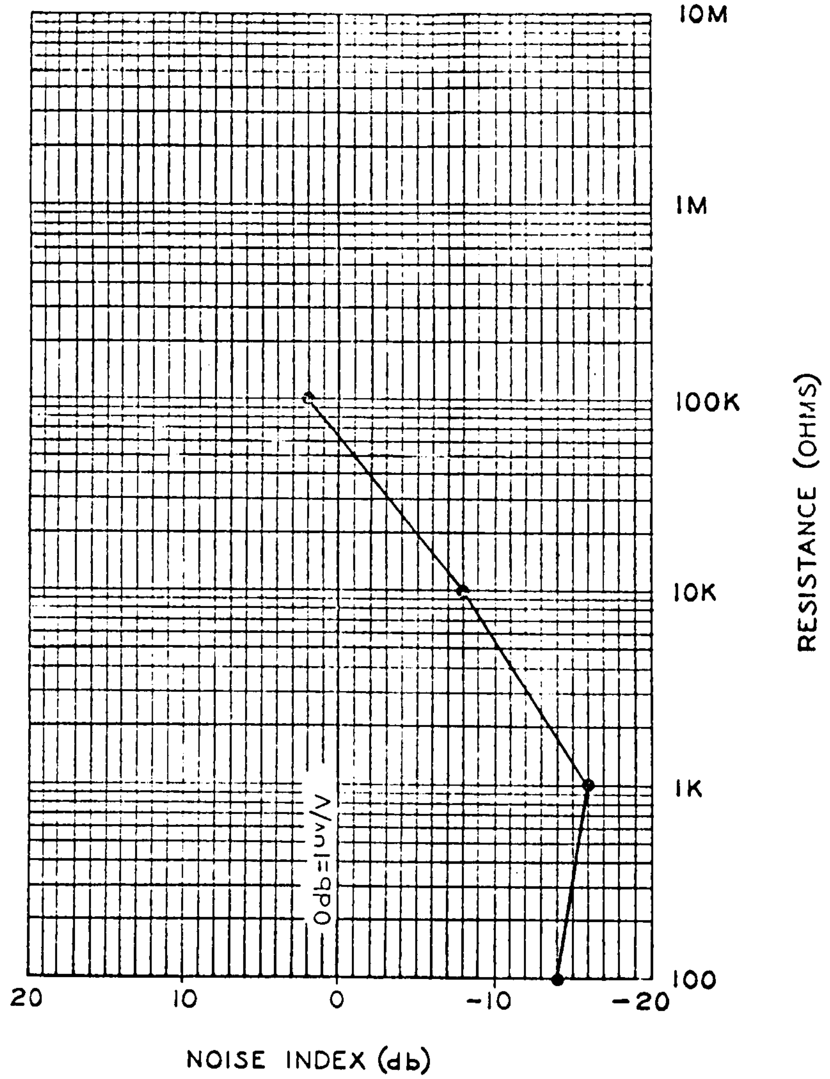
POWER DERATING CURVE FOR HIGH AMBIENT TEMPERATURE

SPECIFICATION CONTROL DOCUMENT

APPROVED	ISSUE DATE	HUGHES AIRCRAFT COMPANY CULVER CITY, CALIFORNIA	STANDARD	REVISED
PROCUREMENT SPECIFICATION NONE		RESISTOR, FIXED, FILM -- DEPOSITED CARBON	988610 PAGE 7 OF 11	(B) (A)

DO NOT SCALE

LIMITS UNLESS OTHERWISE SPECIFIED: .XXX = ± .XX = ± X° = ±



(B) FIGURE 3

MAXIMUM PERMISSIBLE NOISE INDEX

(B)
(A)

SPECIFICATION CONTROL DOCUMENT

APPROVED	ISSUE DATE	HUGHES AIRCRAFT COMPANY CULVER CITY, CALIFORNIA	STANDARD	REV
PROCUREMENT SPECIFICATION NONE		RESISTOR, FIXED, FILM -- DEPOSITED CARBON	98861C PAGE 8 OF 11	

DO NOT SCALE

LIMITS UNLESS OTHERWISE SPECIFIED: .XXX = ± .XX = ± X° = ±

HUGHES NUMBER 988610-	RESISTANCE (OHMS)	HUGHES NUMBER 988610 -	RESISTANCE (OHMS)	HUGHES NUMBER 988610-	RESISTANCE (OHMS)
1	10.0	51	33.2	101	110
2	10.2	52	34.0	102	113
3	10.5	53	34.8	103	115
4	10.7	54	35.7	104	118
5	11.0	55	36.5	105	121
6	11.3	56	37.4	106	124
7	11.5	57	38.3	107	127
8	11.8	58	39.2	108	130
9	12.1	59	40.2	109	133
10	12.4	60	41.2	110	137
11	12.7	61	42.2	111	140
12	13.0	62	43.2	112	143
13	13.3	63	44.2	113	147
14	13.7	64	45.3	114	150
15	14.0	65	46.4	115	154
16	14.3	66	47.5	116	158
17	14.7	67	48.7	117	162
18	15.0	68	49.9	118	165
19	15.4	69	51.1	119	169
20	15.8	70	52.3	120	174
21	16.2	71	53.6	121	178
22	16.5	72	54.9	122	182
23	16.9	73	56.2	123	187
24	17.4	74	57.6	124	191
25	17.8	75	59.0	125	196
26	18.2	76	60.4	126	200
27	18.7	77	61.9	127	205
28	19.1	78	63.4	128	210
29	19.6	79	64.9	129	215
30	20.0	80	66.5	130	221
31	20.5	81	68.1	131	226
32	21.0	82	69.8	132	232
33	21.5	83	71.5	133	237
34	22.1	84	73.2	134	243
35	22.6	85	75.0	135	249
36	23.2	86	76.8	136	255
37	23.7	87	78.7	137	261
38	24.3	88	80.6	138	267
39	24.9	89	82.5	139	274
40	25.5	90	84.5	140	280
41	26.1	91	86.6	141	287
42	26.7	92	88.7	142	294
43	27.4	93	90.9	143	301
44	28.0	94	93.1	144	309
45	28.7	95	95.3	145	316
46	29.4	96	97.6	146	324
47	30.1	97	100	147	332
48	30.9	98	102	148	340
49	31.6	99	105	149	348
50	32.4	100	107	150	357

B

A

SPECIFICATION CONTROL DOCUMENT

APPROVED	ISSUE DATE	HUGHES AIRCRAFT COMPANY CULVER CITY, CALIFORNIA	STANDARD	REVISED
PROCUREMENT SPECIFICATION NONE		RESISTOR, FIXED, FILM -- DEPOSITED CARBON	988610 PAGE 9 OF 11	

DO NOT SCALE

LIMITS UNLESS OTHERWISE SPECIFIED: .XXX = ± .XX = ± X° = ±

HUGHES NUMBER 988610-	RESISTANCE (OHMS)	HUGHES NUMBER 988610-	RESISTANCE (OHMS)	HUGHES NUMBER 988610-	RESISTANCE (OHMS)
151	365	201	1.21K	251	4.02K
152	374	202	1.24K	252	4.12K
153	383	203	1.27K	253	4.22K
154	392	204	1.30K	254	4.32K
155	402	205	1.33K	255	4.42K
156	412	206	1.37K	256	4.53K
157	422	207	1.40K	257	4.64K
158	432	208	1.43K	258	4.75K
159	442	209	1.47K	259	4.87K
160	453	210	1.50K	260	4.99K
161	464	211	1.54K	261	5.11K
162	475	212	1.58K	262	5.23K
163	487	213	1.62K	263	5.36K
164	499	214	1.65K	264	5.49K
165	511	215	1.69K	265	5.62K
166	523	216	1.74K	266	5.76K
167	536	217	1.78K	267	5.90K
168	549	218	1.82K	268	6.04K
169	562	219	1.87K	269	6.19K
170	576	220	1.91K	270	6.34K
171	590	221	1.96K	271	6.49K
172	604	222	2.00K	272	6.65K
173	619	223	2.05K	273	6.81K
174	634	224	2.10K	274	6.98K
175	649	225	2.15K	275	7.15K
176	665	226	2.21K	276	7.32K
177	681	227	2.26K	277	7.50K
178	698	228	2.32K	278	7.68K
179	715	229	2.37K	279	7.87K
180	732	230	2.43K	280	8.06K
181	750	231	2.49K	281	8.25K
182	768	232	2.55K	282	8.45K
183	787	233	2.61K	283	8.66K
184	806	234	2.67K	284	8.87K
185	825	235	2.74K	285	9.09K
186	845	236	2.80K	286	9.31K
187	866	237	2.87K	287	9.53K
188	887	238	2.94K	288	9.76K
189	909	239	3.01K	289	10.00K
190	931	240	3.09K	290	10.2K
191	953	241	3.16K	291	10.5K
192	976	242	3.24K	292	10.7K
193	1.00K	243	3.32K	293	11.0K
194	1.02K	244	3.40K	294	11.3K
195	1.05K	245	3.48K	295	11.5K
196	1.07K	246	3.57K	296	11.8K
197	1.10K	247	3.65K	297	12.1K
198	1.13K	248	3.74K	298	12.4K
199	1.15K	249	3.83K	299	12.7K
200	1.18K	250	3.92K	300	13.0K

SPECIFICATION CONTROL DOCUMENT

APPROVED / ISSUE DATE	HUGHES AIRCRAFT COMPANY CULVER CITY, CALIFORNIA	STANDARD 988610	REVISED B A
PROCUREMENT SPECIFICATION NONE	RESISTOR, FIXED, FILM -- DEPOSITED CARBON	PAGE 10 OF 11	

DO NOT SCALE

LIMITS UNLESS OTHERWISE SPECIFIED: .XXX ± .XX ± X° ±

PART-NUMBER TABLE

HUGHES NUMBER 988610-	RESISTANCE (OHMS)	HUGHES NUMBER 988610-	RESISTANCE (OHMS)	HUGHES NUMBER 988610-	RESISTANCE (OHMS)
301	13.3K	330	26.7K	359	53.6K
302	13.7K	331	27.4K	360	54.9K
303	14.0K	332	28.0K	361	56.2K
304	14.3K	333	28.7K	362	57.6K
305	14.7K	334	29.4K	363	59.0K
306	15.0K	335	30.1K	364	60.4K
307	15.4K	336	30.9K	365	61.9K
308	15.8K	337	31.6K	366	63.4K
309	16.2K	338	32.4K	367	64.9K
310	16.5K	339	33.2K	368	66.5K
311	16.9K	340	34.0K	369	68.1K
312	17.4K	341	34.8K	370	69.8K
313	17.8K	342	35.7K	371	71.5K
314	18.2K	343	36.5K	372	73.2K
315	18.7K	344	37.4K	373	75.0K
316	19.1K	345	38.3K	374	76.8K
317	19.6K	346	39.2K	375	78.7K
318	20.0K	347	40.2K	376	80.6K
319	20.5K	348	41.2K	377	82.5K
320	21.0K	349	42.2K	378	84.5K
321	21.5K	350	43.2K	379	86.6K
322	22.1K	351	44.2K	380	88.7K
323	22.6K	352	45.3K	381	90.9K
324	23.2K	353	46.4K	382	93.1K
325	23.7K	354	47.5K	383	95.3K
326	24.3K	355	48.7K	384	97.6K
327	24.9K	356	49.9K	385	100K
328	25.5K	357	51.1K		
329	26.1K	358	52.3K		

TEXAS INSTRUMENTS TYPE CG-1/8

PROCUREMENT BY HUGHES AIRCRAFT COMPANY IS LIMITED TO THE MANUFACTURERS LISTED HEREIN:

TEXAS INSTRUMENTS, INC., DALLAS, TEX. (CODE IDENT. NO. 06228)

B
A

SPECIFICATION CONTROL DOCUMENT

APPROVED	ISSUE DATE	HUGHES AIRCRAFT COMPANY CULVER CITY, CALIFORNIA	STANDARD	REVISED
PROCUREMENT SPECIFICATION NONE		RESISTOR, FIXED, FILM -- DEPOSITED CARBON	988610 PAGE 11 OF 11	

1. SCOPE

1.1 This addendum covers additional requirements and tests for deposited carbon resistors that have been manufactured to the Hughes Aircraft Company document 988610.

1.2 Purpose. The primary purpose of this addendum is to provide test data correlated to each part, by serialization, to help select the parts with the highest probability of survival in long life spacecraft.

2. APPLICABLE DOCUMENTS

2.1 The following document, of the latest issue in effect, shall apply to this specification to the extent specified herein:

HUGHES AIRCRAFT COMPANY

988610 Resistor, Fixed, Film -- Deposited Carbon

3. REQUIREMENTS

3.1 General. All parts supplied to this addendum shall have been manufactured to meet the requirements specified in the Hughes Aircraft Company document 988610.

3.2 Supplementary Requirements

3.2.1 Serialization. All resistors selected from the manufacturer's lot of parts shall be distinctively serialized in a manner that will provide individual identity for every resistor. All component data supplied in accordance with this addendum shall be identified by this resistor serial number.

3.2.2 Data Submittal and Certification. The requirements for data submittal indicated in 988610 are replaced completely by those contained herein. The data and certification shall accompany the shipment of parts, and the form, content and procedures shall be as indicated in 4.2.

4. TERMS AND PROCEDURES

4.1 Sequence of Events. The sequence of events shall follow the order shown in Table I. The table includes the tests shown in 4.4.1 of 988610, except that the sequence is now compatible with the supplementary requirements.

4.2 Data Submittal and Certification. At least three copies of the data and lead certification shall be placed in an envelope or separate container from the parts. The envelope shall be identified by the Hughes purchase order number.

4.2.1 Lead Certification. The manufacturer shall prepare a certified statement identifying the lead material, nominal diameter and finish, covering similar parts in the shipment.

TABLE I

TESTS AND PROCEDURES

(REPLACES THE SCREENING TESTS OF HAC 988610)

NUMBER OF SPECIMENS	TEST OR PROCEDURE	REFERENCE PARAGRAPH		DATA TO BE SUPPLIED
		REQUIREMENT	TEST	
All	Initial Resistance	--	4.5.3.1*	None
	Seal	4.5.3.2	4.5.3.2	Attributes
	Serialization	3.2.1	--	None
	Noise	4.5.3.4*	4.5.3.4*	Variables
	Power Conditioning	--	4.5.3.3*	None
	Noise	4.5.3.4*	4.5.3.4*	Variables
	Final Resistance	4.5.3.3*	4.5.3.1*	Variables
--	Data Submittal	3.2.2	4.2	--

*Paragraph number per HAC document 988610

ADDENDUM TO

988610

Page 2 of 3

4.2.2 Data Content. The date shall include the following:

a. Measurements of resistance and noise obtained during the tests of Table I.

b. The results of the seal test expressed in quantity tested and quantity rejected.

4.2.3 Data Format. The arrangement of the report shall be at the discretion of the manufacturer, but shall incorporate the following guidelines:

a. A cover sheet shall include the Hughes part number(s), the Hughes purchase order number and the date testing was completed.

b. The contents shall include a summary of the results, showing how many were tested, how many were rejected and in what test, and how many were shipped or returned to stock, etc.

c. Data for discrepant parts shall be encircled.

d. Test conditions under which the data was taken shall be briefly referenced (e.g., noise at +30 db applied).

e. Clarifying notes shall be used to help explain any unusual behavior or procedure. (See 3.2.2 of this addendum.)

1. SCOPE

1.1 This specification covers tantalum, solid-electrolyte, polarized, hermetically sealed, fixed capacitors similar to Styles CS12 (uninsulated case) and CS13 (insulated case) covered by MIL-C-26655/2, but on which special additional requirements are imposed to assure performance reliability in the space and lunar environments for which the capacitors are intended.

2. APPLICABLE DOCUMENTS

2.1 The following documents, of the latest issue in effect, shall apply to this specification to the extent specified herein:

MIL-STD-202	Test Methods for Electronic and Electrical Component Parts
MIL-C-26655/2	Capacitors, Fixed, Solid Electrolyte, Tantalum, Styles CS12 and CS13

3. REQUIREMENTS

3.1 MIL-C-26655/2 Requirements.- The requirements for Styles CS12 and CS13 capacitors specified in MIL-C-26655/2 shall apply to these capacitors, with the following exceptions and modifications:

(a) Detail Requirements.- The dimensions and electrical characteristics for the individual capacitors specified in MIL-C-26655/2 shall be modified, as necessary, to conform to Figure 1 and the part-number table of this specification.

(b) D-C Leakage.- The d-c leakage shall not exceed the limit specified in Table I.

TABLE I.- MAXIMUM D-C LEAKAGE

TEST TEMPERATURE (° C)	D-C LEAKAGE (MAX)
+25°	The applicable value specified in the part-number table of this specification.
+85°	10 times the allowable value at +25° C.
+125°	12.5 times the allowable value at +25° C at two-thirds of the d-c rated voltage.

(c) Marking.- In addition to the marking specified, the body of each capacitor shall be permanently marked with the letter S in a circle.

3.2 Supplementary Requirements.- The capacitors shall meet the following additional requirements:

3.2.1 Production Control.- All capacitors shipped to Hughes Aircraft Company shall be freshly manufactured, drawn from stock only when the quantity specified on the purchase order is 25 or less. Lot identification in manufacture shall be employed to achieve a maximum of continuity in processing and testing of the capacitors; equipment used, test settings, etc., shall be uniform throughout the lot. Partial shipments to Hughes Aircraft Company shall be made only when the quantity ordered exceeds 500.

3.2.2 Material.- The case material shall be hot-solder-dipped brass.

3.2.2.1 Leads.- The material of the leads shall contain not less than 60 percent low-carbon iron by volume, and shall be sheathed in copper and flashed with tin.

3.2.3 Hard-Vacuum Operation.- After the capacitors are tested as specified in 4.5.2, there shall be no evidence of physical damage, the capacitance shall be within ±5 percent of the initial measurement, and the d-c leakage shall not exceed the applicable value specified in the part-number table.

3.2.4 Thermal Shock.- After the capacitors are tested as specified in 4.5.3, there shall be no evidence of physical damage, the capacitance shall be within ±5 percent of the initial measurement, and the d-c leakage shall not exceed the applicable value specified in the part-number table.

3.2.5 Sterilization Capability.- The capacitors shall be capable of withstanding each of the exposures specified in 4.5.4 without degradation of physical or electrical characteristics. After the test, the capacitance shall be within ±5 percent of the initial measurement and the d-c leakage shall not exceed the applicable value specified in the part-number table. (The capacitors shall not be sterilized before shipment.)

3.2.6 Apparent Failure Rate.- When the capacitors are tested as specified in 4.5.5, the apparent instantaneous failure rate shall not exceed the applicable value specified in the part-number table.

3.2.7 Workmanship.- The surfaces shall be clean and free from grease or oil. The leads shall be free of nicks or sharp bends. The soldered termination shall be smooth and small enough to prevent any accumulation of foreign matter between it and the edge of the case. No loose solder particles shall be present. When examined under X-ray as specified in 4.5.7, there shall be no evidence of loose solder particles, resins, or other foreign material.

3.2.8 Screening Tests.- All capacitors shall have been subjected to the 100-percent screening tests specified in Table III.

4. QUALITY ASSURANCE PROVISIONS

4.1 Classification of Tests.- The inspection and testing of the capacitors shall be classified as follows:

(a) Qualification tests. (See 4.2.)

(b) Acceptance tests. (See 4.3.)

4.1.1 Additional Tests.- Nothing shall prevent the manufacturer from taking such additional samples and performing such additional tests as he may deem necessary or desirable to assure conformance to the requirements of this specification. Additional tests may also be conducted by Hughes Aircraft Company to verify data submitted by the manufacturer.

4.2 Qualification Tests.- Hughes Aircraft Company is responsible for the performance of the specified qualification tests. These tests will be conducted by, or at a laboratory designated by, Hughes Aircraft Company.

4.2.1 Test Sample and Routine.- A minimum of 12 specimens shall be subjected to the qualification tests specified in Table II, in the order listed. If a greater number of capacitors is used, the same relative proportions of specimens tested in each group shall be maintained. Selection of capacitance values or electrical ratings will be made at the discretion of Hughes Aircraft Company.

TABLE II.- QUALIFICATION TESTS

TEST GROUP	NUMBER OF SPECIMENS	TEST	REFERENCE PARAGRAPH	
			REQUIREMENT	TEST
I	6	Hard-Vacuum Operation	3.2.3	4.5.2
II	6	Thermal Shock	3.2.4	4.5.3
		Sterilization Capability	3.2.5	4.5.4

4.3 Acceptance Tests.- The manufacturer is responsible for the performance of all 100-percent screening tests in Table III, in the order listed, and for supplying all samples required for such tests.

TABLE III.- 100-PERCENT SCREENING TESTS

NUMBER OF SPECIMENS	TEST	REFERENCE PARAGRAPH	
		REQUIREMENT	TEST
All	Temperature Cycling	--	4.5.6
	Apparent Failure Rate	3.2.6	4.5.5
	D-C Leakage	3.1(b)	1
	Capacitance	1	1
	Dissipation Factor	1	1
	Workmanship	3.2.7	4.5.7

1 Applicable paragraph per MIL-C-26655

4.3.1 Inspection Lot.- An inspection lot shall be consistent with the production-control requirement (see 3.2.1), and shall consist entirely of capacitors of the same case size, capacitance, and voltage rating, offered for inspection at the same time.

4.3.2 Screening-Test Rejections.- Defectives found during the 100-percent screening tests specified in Table III shall be eliminated from the inspection lot. In the event that the quantity remaining in the lot is incompatible with the production-control requirement (see 3.2.1), the entire lot shall be rejected, unless a written waiver relaxing this requirement is granted by Hughes Aircraft Company.

4.3.3 Certification.- The supplier shall certify with each shipment that:

(a) The acceptance tests specified in 4.3 have been performed.

(b) The capacitors meet all the specified requirements.

4.3.4 Data Submittal.- Within two weeks after shipment of the capacitors, the data accumulated in performing the acceptance tests shall be forwarded to Hughes Aircraft Company. The data shall include the measurements of d-c leakage, capacitance, dissipation factor, and the graphs of the apparent failure rate obtained during the 100-percent screening tests. At least three copies of the data shall be sent to the procurement activity of Hughes Aircraft Company; two of the copies shall be enclosed in a separate sealed envelope marked "Attention: Components Department, Code RA-1, Culver City".

4.4 Standard Test Conditions.- Unless otherwise specified, all measurements and tests shall be performed at ambient pressure and humidity, and at an ambient temperature of 25° (+10, -5)° C.

4.5 Methods of Examination and Test

4.5.1 General.- Where no test method is described, the applicable method of MIL-C-26655 shall be used.

4.5.2 Hard-Vacuum Environment.- Before the test, the capacitance and d-c leakage shall be measured. The capacitors shall be placed within a glass container, which shall be evacuated to a pressure of 10^{-8} millimeter of mercury. The pressure shall be maintained at a maximum of 10^{-7} millimeter of mercury for 250 hours. The capacitors shall then be removed from the container, shall be examined for physical damage, and the capacitance and d-c leakage shall be measured. (See 3.2.3.)

4.5.3 Thermal Shock.- Before the test, the capacitance and d-c leakage shall be measured. The capacitors shall be subjected to 5 complete cycles of thermal shock, in accordance with the following procedure: While at room ambient temperature, the capacitors shall be quickly immersed in liquid nitrogen. After 10 minutes of immersion, the capacitors shall be removed and, within 1 minute, shall be placed in an air chamber held at +125° ±3°C. After 10 minutes, the capacitors shall be removed from the chamber and shall be exposed to room ambient temperature for 5 minutes. Upon completion of the 5 cycles, the capacitors shall be examined for physical damage, and the capacitance and d-c leakage shall be measured. (See 3.2.4.)

4.5.4 Sterilization Capability.- Following an initial measurement of capacitance and d-c leakage, the capacitors shall be subjected to the following tests. Upon completion, the capacitors shall be examined for evidence of physical damage, and the capacitance and d-c leakage shall again be measured. (See 3.2.5.)

(a) High Temperature.- Two 36-hour cycles of exposure to a temperature of 125° C. This requirement is considered fulfilled as a consequence of the MIL approval defined in 6.1.2.

(b) Chemical.- A 24-hour exposure to an atmosphere consisting of a mixture of 12 percent ethylene oxide and 88 percent trichlorofluoromethane (Freon 12) by weight, at a temperature of 37.8° C and a relative humidity of 30 to 50 percent.

4.5.5 Apparent Failure Rate.- Prior to test, the capacitors may be preconditioned, at the manufacturer's discretion. The capacitance, dissipation factor, and d-c leakage shall be measured, and the values recorded. The capacitors shall then be subjected to an accelerated burn-in test at the temperature and applied voltage specified in Table IV, selected at the option of the manufacturer. Each hour of test shall be considered to be equivalent to the number of hours shown in the acceleration-factor column. Test voltages and corresponding acceleration factors in excess of those shown in Table IV shall not be permitted.

TABLE IV.- ACCELERATED BURN-IN SCHEDULE

ACCELERATION FACTOR (Hrs/Hr)	D-C TEST VOLTAGE (PERCENT OF RATED VOLTAGE)	
	AT +85° C	AT +125° C
10	116	81
100	132	96
1,000	147.5	112
10,000	163	128

Testing shall continue until a number of catastrophic failures has occurred, and the precise time of each shall be recorded. For the purpose of this test, a catastrophic failure is defined as a leakage resistance equal to or less than the nominal capacitive reactance at 120 cps. The ordered failure data thus obtained shall be plotted on Weibull paper, and the apparent failure rate shall be computed and plotted against time, on a separate graph. Where evidence of a declining apparent failure rate warrants, testing may be continued until the specified rate has been achieved. The graphs of the apparent failure rate shall accompany each lot of capacitors shipped to Hughes Aircraft Company. At the conclusion of the test, measurements of capacitance, dissipation factor, and d-c leakage shall again be recorded, and compared with the readings obtained before the test. Capacitors that exhibit anomalous behavior shall be removed from the lot. (See 3.2.6)

4.5.6 Temperature Cycling.- The capacitors shall be subjected to the temperature-cycling test specified in Method 102, Condition D, of MIL-STD-202, except that the step-3 high temperature shall be +125° C. No measurements are required either before or after cycling.

4.5.7 Workmanship.- Each capacitor shall be externally examined, and shall then be inspected internally by means of X-ray equipment. X-ray inspections shall be made in two perpendicular planes, parallel to the longitudinal axis of the capacitor. (See 3.2.7.)

5. PREPARATION FOR DELIVERY

5.1 Packaging.- The unit package shall contain ten, or a multiple of ten, capacitors (except where obviously unattainable), all with the same part number. The large external shipping container may contain unit packages of different part number. The entire contents of the unit package shall be mounted on one structure that may be easily removed and replaced in the unit package. The arrangement of the capacitors on this structure shall be orderly. The leads shall be accessible without removal of the capacitors from the structure. The capacitors shall be protected by restricting their individual freedom to move and by preventing contact between individual capacitors within the unit package. The unit package shall preferably be provided with one transparent surface through which a parts count can be made without removal of the contents.

5.2 Marking of Unit Packages.- The unit packages shall be externally marked with the manufacturer's name and/or trademark, manufacturer's part number, capacitance, tolerance, rated voltage, date code, and the Hughes number in parentheses. Additional marking is optional. If possible, the specified marking shall appear on the side with the smallest dimension, to permit stacking of unit packages.

6. NOTES

6.1 Approval of Manufacturer

6.1.1 Performance Ability.- The manufacturer shall have demonstrated his ability to supply uniform, reliable products as specified below.

6.1.2 Approval on Military Qualified Products List.- As a minimum requirement, the capability of the manufacturer to supply Style CS12 and CS13 capacitors in accordance with MIL-C-26655/2 shall be evidenced by inclusion of his product on a Military Qualified Products List.

6.1.3 Process Control.- The manufacturer shall submit sufficient information regarding product flow, process control, and any other related data that will establish his understanding and control of the product.

6.1.4 Technical Competence.- The manufacturer shall have demonstrated, by published articles or other information, that he is aware of the behavior of his product. Especially pertinent are reliability programs and statistical studies which aid in predicting failure rates and in determining derating for a-c and d-c stress levels.

6.1.5 Supplementary Information.- Manufacturer acceptability may be determined by the use of other information, including:

(a) Test data available within Hughes Aircraft Company

(b) Test data from interservice data-exchange programs (IDEP)

(c) Previous history of the manufacturer (adherence to delivery schedules, pricing policy, etc.)

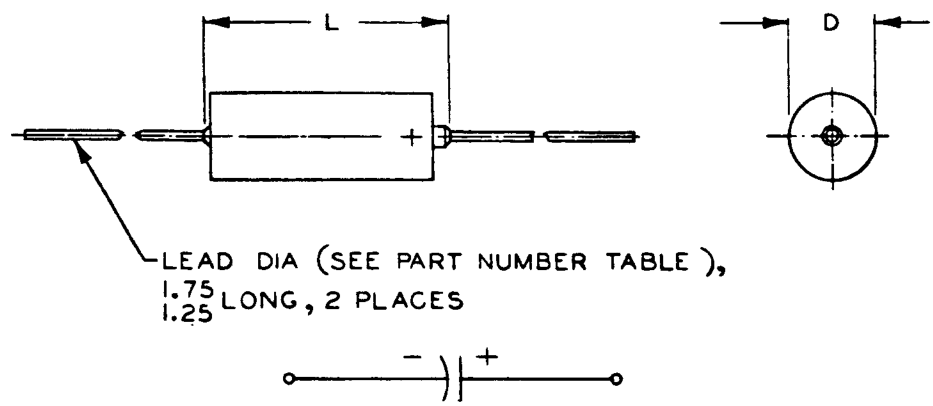
(d) The manufacturer's participation in other high-reliability programs.

(e) Field failure reports.

In recognition of the variable levels of confidence of the aforementioned items, proper consideration will be given to their significance.

DO NOT SCALE

LIMITS UNLESS OTHERWISE SPECIFIED: .XXX =± .XX =± X° =±



SCHEMATIC DIAGRAM

FIGURE 1

PART-NUMBER TABLE

	HUGHES NUMBER 988500-	CAPACITANCE C (µf)	CAPACITANCE TOLERANCE (±%)	D-C RATED VOLTAGE (VOLTS)	D-C LEAKAGE AT 25° C (MICROAMPS)	APPARENT FAILURE RATE (%)	CASE SIZE D (MAX)	CASE SIZE L (MAX)	LEAD DIA (±.001)	KEMET PART NUMBER
2	1	0.33	20	50	0.1	0.01	.130	.410	.020	
	2	0.47			0.1	0.01	.130	.410		
	3	0.68			0.1	0.01	.130	.410		
	4*	1.0			0.2	0.01	.130	.410		
	5	1.5			0.4	0.01	.180	.600		
	6*	2.2			0.5	0.01	.180	.600		
	7	3.3			0.6	0.01	.180	.600		
	8*	4.7			0.8	0.1	.180	.600	.020	
	9	6.8			1.0	0.01	.284	.810	.025	
	10*	10.0			1.0	0.01	.284	.810	.025	
	11	15.0			1.4	0.1	.284	.810	.025	
	12*	22.0			1.4	0.1	.346	.920	.025	
	13	0.0047			0.1	0.01	.130	.410	.020	
	14	0.01			0.1	0.01	.130	.410		
	15	0.022			0.1	0.01	.130	.410		
	16	0.047			0.1	0.01	.130	.410		
	17	0.1			0.1	0.01	.130	.410		
	18	0.22		50	0.1	0.01	.130	.410		
	19	6.8		35	0.2	0.01	.180	.600	.020	
	20*	10.0			0.3	0.01	.284	.810	.025	
	21	15.0			0.3	0.01	.284	.810	.025	
2	22*	22.0	20	35	0.6	0.1	.284	.810	.025	

SPECIFICATION CONTROL DOCUMENT F

APPROVED	ISSUE DATE	HUGHES AIRCRAFT COMPANY CULVER CITY, CALIFORNIA	STANDARD 988500	REVISED
PROCUREMENT SPECIFICATION NONE		CAPACITOR, FIXED, ELECTROLYTIC -- TANTALUM, SOLID ELECTROLYTE	PAGE 7 OF 21	

DO NOT SCALE

LIMITS UNLESS OTHERWISE SPECIFIED: .XXX ± .XX ± X° ±

PART-NUMBER TABLE

	HUGHES NUMBER 988500-	CAPACITANCE C (µf)	CAPACITANCE TOLERANCE (±%)	D-C RATED VOLTAGE (VOLTS)	D-C LEAKAGE AT 25° C (MICROAMPS)	APPARENT FAILURE RATE (%)	CASE SIZE D (MAX)	CASE SIZE L (MAX)	LEAD DIA (±.001)	KEMET PART NUMBER
2	23	33.0	20	35	1.0	0.1	.346	.920	.025	
	24*	47.0		35	1.5	0.1	.346	.920	.025	
	25	1.5		20	0.1	0.01	.130	.410	.020	
	26*	2.2			0.1	0.01	.130	.410	.020	
	27*	10.0			0.2	0.01	.180	.600	.020	
	28	15.0			0.3	0.01	.180	.600	.020	
	29	33.0			0.6	0.1	.284	.810	.025	
	30*	47.0			1.0	0.1	.284	.810	.025	
	31	68.0			1.0	0.1	.346	.920	.025	
	32*	100.0		20	1.8	0.1	.346	.920	.025	
	33	3.3		15	0.1	0.01	.130	.410	.020	
	34*	22.0		15	0.3	0.1	.180	.600	.020	
	35	68.0		15	0.6	0.1	.284	.810	.025	
	36	150.0		15	2.0	0.1	.346	.920	.025	
	37*	4.7		10	0.1	0.01	.130	.410	.020	
	38	33.0			0.3	0.1	.180	.600	.020	
	39*	100.0			0.8	0.1	.284	.810	.025	
	40*	220.0		10	2.0	0.1	.346	.920	.025	
	41	6.8		6	0.1	0.01	.130	.410	.020	
	42*	47.0			0.2	0.1	.180	.600	.020	
	43	150.0			0.6	0.1	.284	.810	.025	
	44*	330.0	20	6	2.0	0.1	.346	.920	.025	
	45	0.33	10	50	0.1	0.01	.130	.410	.020	
	46	0.47			0.1	0.01	.130	.410		
	47	0.68			0.1	0.01	.130	.410		
	48	1.0			0.2	0.01	.130	.410		
	49	1.5			0.4	0.01	.180	.600		
	50	2.2			0.5	0.01	.180	.600		
	51	3.3			0.6	0.01	.180	.600		
	52	4.7			0.8	0.1	.180	.600	.020	
	53	6.8			1.0	0.01	.284	.810	.025	
	54	10.0			1.0	0.01	.284	.810	.025	
	55	15.0			1.4	0.1	.284	.810	.025	
	56	22.0			1.4	0.1	.346	.920	.025	
	57	0.0047			0.1	0.01	.130	.410	.020	
	58	0.01			0.1	0.01	.130	.410		
	59	0.022			0.1	0.01	.130	.410		
	60	0.047			0.1	0.01	.130	.410		
	61	0.1			0.1	0.01	.130	.410		
	62	0.22		50	0.1	0.01	.130	.410		
	63	6.8		35	0.2	0.01	.180	.600	.020	
	64	10.0			0.3	0,01	.284	.810	.025	
	65	15.0			0.3	0.01	.284	.810	.025	
	66	22.0			0.6	0.1	.284	.810	.025	
	67	33.0			1.0	0.1	.346	.920	.025	
2	68	47.0	10	35	1.5	0.1	.346	.920	.025	

SPECIFICATION CONTROL DOCUMENT

APPROVED	ISSUE DATE	HUGHES AIRCRAFT COMPANY CULVER CITY, CALIFORNIA	STANDARD 988500	REVISED F
PROCUREMENT SPECIFICATION NONE		CAPACITOR, FIXED, ELECTROLYTIC -- TANTALUM, SOLID ELECTROLYTE	PAGE 8 OF 21	

DO NOT SCALE

LIMITS UNLESS OTHERWISE SPECIFIED: .XXX = ± .XX = ± X° = ±

PART-NUMBER TABLE

Rev.	HUGHES NUMBER 988500-	CAPACITANCE C (µf)	CAPACITANCE TOLERANCE (±%)	D-C RATED VOLTAGE (VOLTS)	D-C LEAKAGE AT 25° C (MICROAMPS)	APPARENT FAILURE RATE (%)	CASE SIZE D (MAX)	CASE SIZE L (MAX)	LEAD DIA (±.001)	KEMET PART NUMBER
2	69	1.5	10	20	0.1	0.01	.130	.410	.020	
	70	2.2			0.1	0.01	.130	.410	.020	
	71	10.0			0.2	0.01	.180	.600	.020	
	72	15.0			0.3	0.01	.180	.600	.020	
	73	33.0			0.6	0.1	.284	.810	.025	
	74	47.0			1.0	0.1	.284	.810	.025	
	75	68.0			1.0	0.1	.346	.920	.025	
	76	100.0		20	1.8	0.1	.346	.920	.025	
	77	3.3		15	0.1	0.01	.130	.410	.020	
	78	22.0			0.3	0.1	.180	.600	.020	
	79	68.0			0.6	0.1	.284	.810	.025	
	80	150.0		15	2.0	0.1	.346	.920	.025	
	81	4.7		10	0.1	0.01	.130	.410	.020	
	82	33.0			0.3	0.1	.180	.600	.020	
	83	100.0			0.8	0.1	.284	.810	.025	
	84	220.0		10	2.0	0.1	.346	.920	.025	
	85	6.8		6	0.1	0.01	.130	.410	.020	
	86	47.0			0.2	0.1	.180	.600	.020	
	87	150.0			0.6	0.1	.284	.810	.025	
2	88	330.0	10	6	2.0	0.1	.346	.920	.025	
3	89	0.33	20	50	0.1	0.01	.150	.440	.020	
	90	0.47			0.1	0.01	.150	.440		
	91	0.68			0.1	0.01	.150	.440		
	92*	1.0			0.2	0.01	.150	.440		
	93	1.5			0.4	0.01	.200	.630		
	94*	2.2			0.5	0.01	.200	.630		
	95	3.3			0.6	0.01	.200	.630		
	96*	4.7			0.8	0.1	.200	.630	.020	
	97	6.8			1.0	0.01	.304	.840	.025	
	98*	10.0			1.0	0.01	.304	.840	.025	
	99	15.0			1.4	0.1	.304	.840	.025	
	100*	22.0			1.4	0.1	.366	.950	.025	
	101	0.0047			0.1	0.01	.150	.440	.020	
	102	0.01			0.1	0.01	.150	.440		
	103	0.022			0.1	0.01	.150	.440		
	104	0.047			0.1	0.01	.150	.440		
	105	0.1			0.1	0.01	.150	.440		
	106	0.22		50	0.1	0.01	.150	.440		
	107	6.8		35	0.2	0.01	.200	.630	.020	
	108*	10.0			0.3	0.01	.304	.840	.025	
	109	15.0			0.3	0.01	.304	.840	.025	
	110	22.0			0.6	0.1	.304	.840	.025	
	111	33.0			1.0	0.1	.366	.950	.025	
	112*	47.0		35	1.5	0.1	.366	.950	.025	
	113	1.5		20	0.1	0.01	.150	.440	.020	
3	114*	2.2	20	20	0.1	0.01	.150	.440	.020	

SPECIFICATION CONTROL DOCUMENT F

APPROVED	ISSUE DATE	HUGHES AIRCRAFT COMPANY CULVER CITY, CALIFORNIA	STANDARD	REVISED
PROCUREMENT SPECIFICATION NONE		CAPACITOR, FIXED, ELECTROLYTIC -- TANTALUM, SOLID ELECTROLYTE	988500 PAGE 9 OF 21	

DO NOT SCALE

LIMITS UNLESS OTHERWISE SPECIFIED: .XXX = ± .XX = ± X° = ±

PART-NUMBER TABLE

HUGHES NUMBER 988500-	CAPACITANCE C (μf)	TOLER-ANCE (±%)	D-C RATED VOLTAGE (VOLTS)	D-C LEAKAGE AT 25° C (MICROAMPS)	APPARENT FAILURE RATE (%)	CASE SIZE D (MAX)	CASE SIZE L (MAX)	LEAD DIA (±.001)	KEMET PART NUMBER
3 115*	10.0	20	20	0.2	0.01	.200	.630	.020	
116	15.0			0.3	0.01	.200	.630	.020	
117	33.0			0.6	0.1	.304	.840	.025	
118*	47.0			1.0	0.1	.304	.840	.025	
119	68.0			1.0	0.1	.366	.950	.025	
120*	100.0		20	1.8	0.1	.366	.950	.025	
121	3.3		15	0.1	0.01	.150	.440	.020	
122*	22.0			0.3	0.1	.200	.630	.020	
123	68.0			0.6	0.1	.304	.840	.025	
124	150.0		15	2.0	0.1	.366	.950	.025	
125*	4.7		10	0.1	0.01	.150	.440	.020	
126	33.0			0.3	0.1	.200	.630	.020	
127*	100.0			0.8	0.1	.304	.840	.025	
128*	220.0		10	2.0	0.1	.366	.950	.025	
129	6.8		6	0.1	0.01	.150	.440	.020	
130*	47.0			0.2	0.1	.200	.630	.020	
131	150.0			0.6	0.1	.304	.840	.025	
132	330.0	20	6	2.0	0.1	.366	.950	.025	
133	0.33	10	50	0.1	0.01	.150	.440	.020	
134	0.47			0.1	0.01	.150	.440		
135	0.68			0.1	0.01	.150	.440		
136	1.0			0.2	0.01	.150	.440		
137	1.5			0.4	0.01	.200	.630		
138	2.2			0.5	0.01	.200	.630		
139	3.3			0.6	0.01	.200	.630		
140	4.7			0.8	0.1	.200	.630	.020	
141	6.8			1.0	0.01	.304	.840	.025	
142	10.0			1.0	0.01	.304	.840	.025	
143	15.0			1.4	0.1	.304	.840	.025	
144	22.0			1.4	0.1	.366	.950	.025	
145	0.0047			0.1	0.01	.150	.440	.020	
146	0.01			0.1	0.01	.150	.440		
147	0.022			0.1	0.01	.150	.440		
148	0.047			0.1	0.01	.150	.440		
149	0.1			0.1	0.01	.150	.440		
150	0.22		50	0.1	0.01	.150	.440		
151	6.8		35	0.2	0.01	.200	.630	.020	
152	10.0			0.3	0.01	.304	.840	.025	
153	15.0			0.3	0.01	.304	.840	.025	
154	22.0			0.6	0.1	.304	.840	.025	
155	33.0			1.0	0.1	.366	.950	.025	
156	47.0		35	1.5	0.1	.366	.950	.025	
157	1.5		20	0.1	0.01	.150	.440	.020	
158	2.2			0.1	0.01	.150	.440	.020	
159	10.0			0.2	0.01	.200	.630	.020	
160	15.0			0.3	0.01	.200	.630	.020	
161	33.0			0.6	0.1	.304	.840	.025	
3 162	47.0	10	20	1.0	0.1	.304	.840	.025	

SPECIFICATION CONTROL DOCUMENT F

APPROVED	ISSUE DATE	HUGHES AIRCRAFT COMPANY CULVER CITY, CALIFORNIA	STANDARD 988500	REVISED
PROCUREMENT SPECIFICATION NONE		CAPACITOR, FIXED, ELECTROLYTIC -- TANTALUM, SOLID ELECTROLYTE	PAGE 10 OF 21	

DO NOT SCALE

LIMITS UNLESS OTHERWISE SPECIFIED: .XXX = ± .XX = ± X° = ±

PART-NUMBER TABLE

HUGHES NUMBER 988500-	CAPACITANCE C (μf)	TOLERANCE (±%)	D-C RATED VOLTAGE (VOLTS)	D-C LEAKAGE AT 25° C (MICROAMPS)	APPARENT FAILURE RATE (%)	CASE SIZE D (MAX)	CASE SIZE L (MAX)	LEAD DIA (±.001)	KEMET PART NUMBER
(3) 163	68.0	10	20	1.0	0.1	.366	.950	.025	
164	100.0		20	1.8	0.1	.366	.950	.025	
165	3.3		15	0.1	0.01	.150	.440	.020	
166	22.0			0.3	0.1	.200	.630	.020	
167	68.0			0.6	0.1	.304	.840	.025	
168	150.0		15	2.0	0.1	.366	.950	.025	
169	4.7		10	0.1	0.01	.150	.440	.020	
170	33.0			0.3	0.1	.200	.630	.020	
171	100.0			0.8	0.1	.304	.840	.025	
172	220.0		10	2.0	0.1	.366	.950	.025	
173	6.8		6	0.1	0.01	.150	.440	.020	
174	47.0			0.2	0.1	.200	.630	.020	
175	150.0			0.6	0.1	.304	.840	.025	
(3) 176	330.0	10	6	2.0	0.1	.366	.950	.025	
(2) 177	.0047	5	50	0.1	0.01	.130	.410	.020	
178	.0068								
179	.01								
180	.012								
181	.015								
182	.018								
183	.022								
184	.027								
185	.033								
186	.039								
187	.047								
188	.056								
189	.068								
190	.082								
191	0.1								
192	.12								
193	.15								
194	.18								
195	.22								
196	.27								
197	.33								
198	.39								
199	.47								
200	.56								
201	.68			0.1					
202	.82			0.2					
203	1.0			0.2		.130	.410		
204	1.2			0.4		.180	.600		
205	1.5			0.4					
206	1.8			0.5					
207	2.2			0.5					
208	2.7			0.6					
(2) 209	3.3	5	50	0.6	0.01	.180	.600	.020	

SPECIFICATION CONTROL DOCUMENT (F)

APPROVED	ISSUE DATE	HUGHES AIRCRAFT COMPANY CULVER CITY, CALIFORNIA	STANDARD	REVISED
PROCUREMENT SPECIFICATION NONE		CAPACITOR, FIXED, ELECTROLYTIC -- TANTALUM, SOLID ELECTROLYTE	988500 PAGE 11 OF 21	

DO NOT SCALE

LIMITS UNLESS OTHERWISE SPECIFIED: .XXX = ± .XX = ± X° = ±

PART-NUMBER TABLE

HUGHES NUMBER 988500-	CAPACITANCE C (µf)	CAPACITANCE TOLERANCE (±%)	D-C RATED VOLTAGE (VOLTS)	D-C LEAKAGE AT 25° C (MICROAMPS)	APPARENT FAILURE RATE (%)	CASE SIZE D (MAX)	CASE SIZE L (MAX)	LEAD DIA (±.001)	KEMET PART NUMBER
2 210	3.9	5	50	0.8	0.01	.180	.600	.020	
211	4.7			0.8	0.1	.180	.600	.020	
212	5.6			1.0	0.01	.284	.810	.025	
213	6.8			1.0	0.01				
214	8.2			1.0	0.01				
215	10.0			1.0	0.01				
216	12.0			1.4	0.01				
217	15.0			1.4	0.1	.284	.810		
218	18.0			1.4	0.01	.346	.920		
219	22.0		50	1.4	0.1	.346	.920	.025	
220	5.6		35	0.2	0.01	.180	.600	.020	
221	6.8			0.2	0.01	.180	.600	.020	
222	8.2			0.2	0.01	.284	.810	.025	
223	10.0			0.3	0.01				
224	12.0			0.3	0.01				
225	15.0			0.3	0.01				
226	18.0			0.6	0.01				
227	22.0			0.6	0.1	.284	.810		
228	27.0			1.0	0.1	.346	.920		
229	33.0			1.0	0.1				
230	39.0			1.5	0.1				
231	47.0		35	1.5	0.1	.346	.920	.025	
232	1.2		20	0.1	0.01	.130	.410	.020	
233	1.5			0.1	0.01				
234	1.8			0.1	0.01				
235	2.2			0.1	0.01	.130	.410		
236	8.2			0.2	0.01	.180	.600		
237	10.0			0.2	0.01				
238	12.0			0.2	0.01				
239	15.0			0.3	0.01	.180	.600	.020	
240	27.0			0.6	0.1	.284	.810	.025	
241	33.0			0.6	0.1				
242	39.0			1.0	0.1				
243	47.0			1.0	0.1	.284	.810		
244	56.0			1.0	0.1	.346	.920		
245	68.0			1.0	0.1				
246	82.0			1.8	0.1				
247	100.0		20	1.8	0.1	.346	.920	.025	
248	2.7		15	0.1	0.01	.130	.410	.020	
249	3.3			0.1	0.01	.130	.410		
250	18.0			0.2	0.01	.180	.600		
251	22.0			0.3	0.1	.180	.600	.020	
252	56.0			0.6	0.1	.284	.810	.025	
253	68.0			0.6	0.1	.284	.810		
254	120.0			2.0	0.1	.346	.920		
2 255	150.0	5	15	2.0	0.1	.346	.920	.025	

SPECIFICATION CONTROL DOCUMENT

F REVIS

APPROVED	ISSUE DATE	HUGHES AIRCRAFT COMPANY CULVER CITY, CALIFORNIA	STANDARD 988500
PROCUREMENT SPECIFICATION NONE		CAPACITOR, FIXED, ELECTROLYTIC -- TANTALUM, SOLID ELECTROLYTE	PAGE 12 OF 21

DO NOT SCALE

LIMITS UNLESS OTHERWISE SPECIFIED: .XXX = ± .XX = ± X° = ±

PART-NUMBER TABLE

HUGHES NUMBER 988500-	CAPACITANCE C (µf)	CAPACITANCE TOLERANCE (±%)	D-C RATED VOLTAGE (VOLTS)	D-C LEAKAGE AT 25° C (MICROAMPS)	APPARENT FAILURE RATE (%)	CASE SIZE D (MAX)	CASE SIZE L (MAX)	LEAD DIA (±.001)	KEMET PART NUMBER
2 256	3.9	5	10	0.1	0.01	.130	.410	.020	
257	4.7			0.1	0.01	.130	.410	.020	
258	27.0			0.3	0.01	.180	.600	.020	
259	33.0			0.3	0.1	.180	.600	.020	
260	82.0			0.8	0.01	.284	.810	.025	
261	100.0			0.8	0.1	.284	.810		
262	180.0			2.0	0.01	.346	.920		
263	220.0		10	2.0	0.1	.346	.920	.025	
264	5.6		6	0.1	0.01	.130	.410	.020	
265	6.8			0.1	0.01	.130	.410		
266	39.0			0.2	0.01	.180	.600		
267	47.0			0.3	0.1	.180	.600	.020	
268	120.0			0.6	0.01	.284	.810	.025	
269	150.0			0.6	0.1	.284	.810		
270	270.0			2.0	0.01	.346	.920		
2 271	330.0		6	2.0	0.1	.346	.920		
4 272	47.0		35	1.5	0.1	.346	.920		
4 273	100.0		20	1.8	0.1	.346	.920	.025	
3 274	0.0047		50	0.1	0.01	.150	.440	.020	
275	0.0068								
276	0.01								
277	0.012								
278	0.015								
279	0.018								
280	0.022								
281	0.027								
282	0.033								
283	0.039								
284	0.047								
285	0.056								
286	0.068								
287	0.082								
288	0.1								
289	0.12								
290	0.15								
291	0.18								
292	0.22								
293	0.27								
294	0.33								
295	0.39								
296	0.47								
297	0.56								
298	0.68			0.1					
299	0.82			0.2					
3 300	1.0	5	50	0.2	0.01	.150	.440	.020	

SPECIFICATION CONTROL DOCUMENT

F

APPROVED	ISSUE DATE	HUGHES AIRCRAFT COMPANY CULVER CITY, CALIFORNIA	STANDARD	REVISE
PROCUREMENT SPECIFICATION NONE		CAPACITOR, FIXED, ELECTROLYTIC -- TANTALUM, SOLID ELECTROLYTE	988500 PAGE 13 OF 21	

DO NOT SCALE

LIMITS UNLESS OTHERWISE SPECIFIED: .XXX = ± .XX = ± X° = ±

PART-NUMBER TABLE

HUGHES NUMBER 988500-	CAPACITANCE C (μf)	TOLERANCE (±%)	D-C RATED VOLTAGE (VOLTS)	D-C LEAKAGE AT 25° C (MICROAMPS)	APPARENT FAILURE RATE (%)	CASE SIZE D (MAX)	CASE SIZE L (MAX)	LEAD DIA (±.001)	KEMET PART NUMBER
3 301	1.2	5	50	0.4	0.01	.200	.630	.020	
302	1.5			0.4	0.01				
303	1.8			0.5	0.01				
304	2.2			0.5	0.01				
305	2.7			0.6	0.01				
306	3.3			0.6	0.01				
307	3.9			0.8	0.01				
308	4.7			0.8	0.1	.200	.630	.020	
309	5.6			1.0	0.01	.304	.840	.025	
310	6.8			1.0	0.01				
311	8.2			1.0	0.01				
312	10.0			1.0	0.01				
313	12.0			1.4	0.01				
314	15.0			1.4	0.1	.304	.840		
315	18.0			1.4	0.01	.366	.950		
316	22.0		50	1.4	0.1	.366	.950	.025	
317	5.6		35	0.2	0.01	.200	.630	.020	
318	6.8			0.2	0.01	.200	.630	.020	
319	8.2			0.2	0.01	.304	.840	.025	
320	10.0			0.3	0.01				
321	12.0			0.3	0.01				
322	15.0			0.3	0.01				
323	18.0			0.6	0.01				
324	22.0			0.6	0.1	.304	.840		
325	27.0			1.0	0.1	.366	.950		
326	33.0			1.0	0.1	.366	.950		
327	39.0			1.5	0.1	.366	.950		
328	47.0		35	1.5	0.1	.366	.950	.025	
329	1.2		20	0.1	0.01	.150	.440	.020	
330	1.5			0.1	0.01	.150	.440		
331	1.8			0.1	0.01	.150	.440		
332	2.2			0.1	0.01	.150	.440		
333	8.2			0.2	0.01	.200	.630		
334	10.0			0.2	0.01	.200	.630		
335	12.0			0.2	0.01	.200	.630		
336	15.0			0.3	0.01	.200	.630	.020	
337	27.0			0.6	0.1	.304	.840	.025	
338	33.0			0.6	0.1	.304	.840		
339	39.0			1.0	0.1	.304	.840		
340	47.0			1.0	0.1	.304	.840		
341	56.0			1.0	0.1	.366	.950		
342	68.0			1.0	0.1	.366	.950		
343	82.0			1.8	0.1	.366	.950		
344	100.0		20	1.8	0.1	.366	.950	.025	
345	2.7		15	0.1	0.01	.150	.440	.020	
346	3.3			0.1	0.01	.150	.440	.020	
347	18.0			0.2	0.01	.200	.630	.020	
3 348	22.0	5	15	0.3	0.1	.200	.630	.020	

SPECIFICATION CONTROL DOCUMENT

F REVISE

APPROVED	ISSUE DATE	HUGHES AIRCRAFT COMPANY CULVER CITY, CALIFORNIA	STANDARD 988500
PROCUREMENT SPECIFICATION NONE		CAPACITOR, FIXED, ELECTROLYTIC -- TANTALUM, SOLID ELECTROLYTE	PAGE 14 OF 21

DO NOT SCALE

LIMITS UNLESS OTHERWISE SPECIFIED: .XXX ± .XX ± X° ±

PART-NUMBER TABLE

HUGHES NUMBER 988500-	CAPACITANCE C (µf)	CAPACITANCE TOLERANCE (±%)	D-C RATED VOLTAGE (VOLTS)	D-C LEAKAGE AT 25° C (MICROAMPS)	APPARENT FAILURE RATE (%)	CASE SIZE D (MAX)	CASE SIZE L (MAX)	LEAD DIA (±.001)	KEMET PART NUMBER
3 349	56.0	5	15	0.6	0.01	.304	.840	.025	
350	68.0			0.6	0.1	.304	.840	.025	
351	120.0			2.0	0.01	.366	.950	.025	
352	150.0		15	2.0	0.1	.366	.950	.025	
353	3.9		10	0.1	0.01	.150	.440	.020	
354	4.7			0.1	0.01	.150	.440	.020	
355	27.0			0.3	0.01	.200	.630	.020	
356	33.0			0.3	0.1	.200	.630	.020	
357	82.0			0.8	0.01	.304	.840	.025	
358	100.0			0.8	0.1	.304	.840	.025	
359	180.0			2.0	0.01	.366	.950	.025	
360	220.0		10	2.0	0.1	.366	.950	.025	
361	5.6		6	0.1	0.01	.150	.440	.020	
362	6.8			0.1	0.01	.150	.440	.020	
363	39.0			0.2	0.01	.200	.630	.020	
364	47.0			0.3	0.1	.200	.630	.020	
365	120.0			0.6	0.01	.304	.840	.025	
366	150.0			0.6	0.1	.304	.840	.025	
367	270.0			2.0	0.01	.366	.950	.025	
3 368	330.0	5	6	2.0	0.1	.366	.950	.025	
2 369	0.1	20	75	1	0.1	.130	.410	.020	
370	0.15								
371	0.22								
372	0.33								
373	0.47			1					
374	0.68			2		.130	.410		
375	1.0			2		.180	.600		
376	1.5			4		.180	.600		
377	2.2			4		.180	.600		
378	3.3			6		.180	.600	.020	
379	4.7			6		.284	.810	.025	
380	6.8			10		.284	.810	.025	
381	10.0			10		.284	.810	.025	
2 382	15.0			14		.346	.920	.025	
3 383	0.1			1		.150	.440	.020	
384	0.15								
385	0.22								
386	0.33								
387	0.47			1					
388	0.68			2		.150	.440		
389	1.0			2		.200	.630		
390	1.5			4		.200	.630		
391	2.2			4		.200	.630		
392	3.3			6		.200	.630	.020	
393	4.7			6		.304	.840	.025	
394	6.8			10		.304	.840	.025	
395	10.0			10		.304	.840	.025	
3 396	15.0	20	75	14	0.1	.366	.950	.025	

SPECIFICATION CONTROL DOCUMENT F

APPROVED	ISSUE DATE	HUGHES AIRCRAFT COMPANY CULVER CITY, CALIFORNIA	STANDARD	REVISED
PROCUREMENT SPECIFICATION NONE		CAPACITOR, FIXED, ELECTROLYTIC -- TANTALUM, SOLID ELECTROLYTE	988500 PAGE 15 OF 21	

DO NOT SCALE

LIMITS UNLESS OTHERWISE SPECIFIED: .XXX = ± .XX = ± X° = ±

PART-NUMBER TABLE

HUGHES NUMBER 988500-	CAPACITANCE C (µf)	CAPACITANCE TOLER-ANCE (±%)	D-C RATED VOLTAGE (VOLTS)	D-C LEAKAGE AT 25° C (MICROAMPS)	APPARENT FAILURE RATE (%)	CASE SIZE D (MAX)	CASE SIZE L (MAX)	LEAD DIA (±.001)	KEMET PART NUMBER
2 397	0.1	10	75	1	0.1	.130	.410	.020	
398	0.12								
399	0.15								
400	0.18								
401	0.22								
402	0.27								
403	0.33								
404	0.39								
405	0.47								
406	0.56			1					
407	0.68			2		.130	.410		
408	0.82			2		.180	.600		
409	1.0			2					
410	1.2			2					
411	1.5			4					
412	1.8			4					
413	2.2			4					
414	2.7			4					
415	3.3			6					
416	3.9			6		.180	.600	.020	
417	4.7			6		.284	.810	.025	
418	5.6			6					
419	6.8			10					
420	8.2			10					
421	10.0			10		.284	.810		
422	12.0			10		.346	.920		
2 423	15.0			14		.346	.920	.025	
3 424	0.1			1		.150	.440	.020	
425	0.12								
426	0.15								
427	0.18								
428	0.22								
429	0.27								
430	0.33								
431	0.39								
432	0.47								
433	0.56			1					
434	0.68			2		.150	.440		
435	0.82			2		.200	.630		
436	1.0			2					
437	1.2			2					
438	1.5			4					
439	1.8			4					
440	2.2			4					
441	2.7			4					
442	3.3			6					
3 443	3.9	10	75	6	0.1	.200	.630	.020	

SPECIFICATION CONTROL DOCUMENT F

APPROVED	ISSUE DATE	HUGHES AIRCRAFT COMPANY CULVER CITY, CALIFORNIA	STANDARD 988500	REVISE
PROCUREMENT SPECIFICATION NONE		CAPACITOR, FIXED, ELECTROLYTIC -- TANTALUM, SOLID ELECTROLYTE	PAGE 16 OF 21	

DO NOT SCALE

LIMITS UNLESS OTHERWISE SPECIFIED: .XXX = ± .XX = ± X° = ±

PART NUMBER TABLE

HUGHES NUMBER 988500-	CAPACITANCE C (µf)	CAPACITANCE TOLERANCE (±%)	D-C RATED VOLTAGE (VOLTS)	D-C LEAKAGE AT 25° C (MICROAMPS)	APPARENT FAILURE RATE (%)	CASE SIZE D (MAX)	CASE SIZE L (MAX)	LEAD DIA (±.001)	KEMET PART NUMBER
3 444	4.7	10	75	6	0.1	.304	.840	.025	
445	5.6			6					
446	6.8			10					
447	8.2			10					
448	10.0			10		.304	.840		
449	12.0			10		.366	.950		
3 450	15.0	10		14		.366	.950	.025	
2 451	0.1	5		1		.130	.410	.020	
452	0.12								
453	0.15								
454	0.18								
455	0.22								
456	0.27								
457	0.33								
458	0.39								
459	0.47								
460	0.56			1					
461	0.68			2		.130	.410		
462	0.82			2		.180	.600		
463	1.0			2					
464	1.2			2					
465	1.5			4					
466	1.8			4					
467	2.2			4					
468	2.7			4					
469	3.3			6					
470	3.9			6		.180	.600	.020	
471	4.7			6		.284	.810	.025	
472	5.6			6					
473	6.8			10					
474	8.2			10					
475	10.0			10		.284	.810		
476	12.0			10		.346	.920		
2 477	15.0			14		.346	.920	.025	
3 478	0.1			1		.150	.440	.020	
479	0.12								
480	0.15								
481	0.18								
482	0.22								
483	0.27								
484	0.33								
485	0.39								
486	0.47								
487	0.56			1					
488	0.68			2		.150	.440		
489	0.82			2		.200	.630		
490	1.0			2		.200	.630		
3 491	1.2	5	75	2	0.1	.200	.630	.020	

SPECIFICATION CONTROL DOCUMENT

F REVISED

APPROVED / ISSUE DATE	HUGHES AIRCRAFT COMPANY CULVER CITY, CALIFORNIA	STANDARD 988500
PROCUREMENT SPECIFICATION NONE	CAPACITOR, FIXED, ELECTROLYTIC -- TANTALUM, SOLID ELECTROLYTE	PAGE 17 OF 21

DO NOT SCALE

LIMITS UNLESS OTHERWISE SPECIFIED: .XXX = ± .XX = ± X° = ±

PART-NUMBER TABLE

HUGHES NUMBER 988500-	CAPACITANCE C (µf)	CAPACITANCE TOLERANCE (±%)	D-C RATED VOLTAGE (VOLTS)	D-C LEAKAGE AT 25° C (MICROAMPS)	APPARENT FAILURE RATE (%)	CASE SIZE D (MAX)	CASE SIZE L (MAX)	LEAD DIA (±.001)	KEMET PART NUMBER
3 492	1.5	5	75	4	0.1	.200	.630	.020	
493	1.8			4					
494	2.2			4					
495	2.7			4					
496	3.3			6					
497	3.9			6		.200	.630	.020	
498	4.7			6		.304	.840	.025	
499	5.6			6					
500	6.8			10					
501	8.2			10					
502	10.0			10		.304	.840		
503	12.0			10		.366	.950		
3 504	15.0	5	75	14		.366	.950	.025	
2 505*	4.7	20	50	0.8		.180	.600	.020	
506	15.0		50	1.4		.284	.810	.02	
507*	22.0		50	1.4		.346	.920		
508	22.0		35	0.6		.284	.810		
509	33.0		35	1.0		.346	.920		
510*	47.0		35	1.5		.346	.920		
511	33.0		20	0.6		.284	.810		
512*	47.0		20	1.0		.284	.810		
513	68.0		20	1.0		.346	.920		
514*	100.0		20	1.8		.346	.920	.025	
515*	22.0		15	0.3		.180	.600	.020	
516	68.0		15	0.6		.284	.810	.025	
517	150.0		15	2.0		.346	.920	.025	
518	33.0		10	0.3		.180	.600	.020	
519*	100.0		10	0.8		.284	.810	.025	
520*	220.0		10	2.0		.346	.920	.025	
521*	47.0		6	0.2		.180	.600	.020	
522	150.0		6	0.6		.284	.810	.025	
523*	330.0	20	6	2.0		.346	.920	.025	
524	4.7	10	50	0.8		.180	.600	.020	
525	15.0		50	1.4		.284	.810	.025	
526	22.0		50	1.4		.346	.920		
527	22.0		35	0.6		.284	.810		
528	33.0		35	1.0		.346	.920		
529	47.0		35	1.5		.346	.920		
530	33.0		20	0.6		.284	.810		
531	47.0		20	1.0		.284	.810		
532	68.0		20	1.0		.346	.920		
533	100.0		20	1.8		.346	.920	.025	
534	22.0		15	0.3		.180	.600	.020	
535	68.0		15	0.6		.284	.810	.025	
536	150.0		15	2.0		.346	.920	.025	
537	33.0		10	0.3		.180	.600	.020	
538	100.0		10	0.8		.284	.810	.025	
2 539	220.0	10	10	2.0	0.1	.346	.920	.025	

SPECIFICATION CONTROL DOCUMENT F

APPROVED	ISSUE DATE	HUGHES AIRCRAFT COMPANY CULVER CITY, CALIFORNIA	STANDARD	REVISED
PROCUREMENT SPECIFICATION NONE		CAPACITOR, FIXED, ELECTROLYTIC -- TANTALUM, SOLID ELECTROLYTE	988500 PAGE 18 OF 21	

DO NOT SCALE

LIMITS UNLESS OTHERWISE SPECIFIED: .XXX = ± .XX = ± X° = ±

PART-NUMBER TABLE

HUGHES NUMBER 988500-	CAPACITANCE C (µf)	CAPACITANCE TOLER-ANCE (±%)	D-C RATED VOLTAGE (VOLTS)	D-C LEAKAGE AT 25° C (MICROAMPS)	APPARENT FAILURE RATE (%)	CASE SIZE D (MAX)	CASE SIZE L (MAX)	LEAD DIA (±.001)	KEMET PART NUMBER
2 540	47.0	10	6	0.2	0.01	.180	.600	.020	
541	150.0	10	6	0.6		.284	.810	.025	
542	330.0	10	6	2.0		.346	.920	.025	
543*	4.7	20	50	0.8		.200	.630	.020	
544	15.0		50	1.4		.304	.840	.025	
545*	22.0		50	1.4		.366	.950		
546	22.0		35	0.6		.304	.840		
547	33.0		35	1.0		.366	.950		
548*	47.0		35	1.5		.366	.950		
549	33.0		20	0.6		.304	.840		
550*	47.0		20	1.0		.304	.840		
551	68.0		20	1.0		.366	.950		
552*	100.0		20	1.8		.366	.950	.025	
553*	22.0		15	0.3		.200	.630	.020	
554	68.0		15	0.6		.304	.840	.025	
555	150.0		15	2.0		.366	.950	.025	
556	33.0		10	0.3		.200	.630	.020	
557*	100.0		10	0.8		.304	.840	.025	
558*	220.0		10	2.0		.366	.950	.025	
559*	47.0		6	0.2		.200	.630	.020	
560	150.0		6	0.6		.304	.840	.025	
561	330.0	20	6	2.0		.366	.950	.025	
562	4.7	10	50	0.8		.200	.630	.020	
563	15.0		50	1.4		.304	.840	.025	
564	22.0		50	1.4		.366	.950		
565	22.0		35	0.6		.304	.840		
566	33.0		35	1.0		.366	.950		
567	47.0		35	1.5		.366	.950		
568	33.0		20	0.6		.304	.840		
569	47.0		20	1.0		.304	.840		
570	68.0		20	1.0		.366	.950		
571	100.0		20	1.8		.366	.950	.025	
572	22.0		15	0.3		.200	.630	.020	
573	68.0		15	0.6		.304	.840	.025	
574	150.0		15	2.0		.366	.950	.025	
575	33.0		10	0.3		.200	.630	.020	
576	100.0		10	0.8		.304	.840	.025	
577	220.0		10	2.0		.366	.950	.025	
578	47.0		6	0.2		.200	.630	.020	
579	150.0		6	0.6		.304	.840	.025	
580	330.0	10	6	2.0		.366	.950	.025	
581	4.7	5	50	0.8		.180	.600	.020	
582	15.0		50	1.4		.284	.810	.025	
583	22.0		50	1.4		.346	.920		
584	22.0		35	0.6		.284	.810		
585	27.0			1.0		.346	.920		
586	33.0			1.0		.346	.920		
2 587	39.0	5	35	1.5	0.01	.346	.920	.025	

SPECIFICATION CONTROL DOCUMENT F

APPROVED	ISSUE DATE	HUGHES AIRCRAFT COMPANY CULVER CITY, CALIFORNIA	STANDARD
PROCUREMENT SPECIFICATION NONE		CAPACITOR, FIXED, ELECTROLYTIC -- TANTALUM, SOLID ELECTROLYTE	988500 PAGE 19 OF 21

REVISE

DO NOT SCALE

LIMITS UNLESS OTHERWISE SPECIFIED: .XXX = ± .XX = ± X° = ±

PART-NUMBER TABLE

	HUGHES NUMBER 988500-	CAPACITANCE C (µf)	CAPACITANCE TOLERANCE (±%)	D-C RATED VOLTAGE (VOLTS)	D-C LEAKAGE AT 25° C (MICROAMPS)	APPARENT FAILURE RATE (%)	CASE SIZE D (MAX)	CASE SIZE L (MAX)	LEAD DIA (±.001)	KEMET PART NUMBER
2	588	47.0	5	35	1.5	0.01	.346	.920	.025	
	589	27.0		20	0.6		.284	.810		
	590	33.0			0.6		.284	.810		
	591	39.0			1.0		.284	.810		
	592	47.0			1.0		.284	.810		
	593	56.0			1.0		.346	.920		
	594	68.0			1.0		.346	.920		
	595	82.0			1.8		.346	.920		
	596	100.0		20	1.8		.346	.920	.025	
	597	22.0		15	0.3		.180	.600	.020	
	598	56.0		15	0.6		.284	.810	.025	
	599	68.0		15	0.6		.284	.810	.025	
	600	120.0		15	2.0		.346	.920	.025	
	601	150.0		15	2.0		.346	.920	.025	
	602	33.0		10	0.3		.180	.600	.025	
	603	100.0		10	0.8		.284	.810	.025	
	604	220.0		10	2.0		.346	.920	.025	
	605	47.0		6	0.3		.180	.600	.020	
	606	150.0		6	0.6		.284	.810	.025	
2	607	330.0		6	2.0		.346	.920	.025	
4	608	47.0		35	1.5		.346	.920	.025	
4	609	100.0		20	1.8		.346	.920	.025	
3	610	4.7		50	0.8		.200	.630	.020	
	611	15.0		50	1.4		.304	.840	.025	
	612	22.0		50	1.4		.366	.950		
	613	22.0		35	0.6		.304	.840		
	614	27.0			1.0		.366	.950		
	615	33.0			1.0		.366	.950		
	616	39.0			1.5		.366	.950		
	617	47.0		35	1.5		.366	.950		
	618	27.0		20	0.6		.304	.840		
	619	33.0			0.6		.304	.840		
	620	39.0			1.0		.304	.840		
	621	47.0			1.0		.304	.840		
	622	56.0			1.0		.366	.950		
	623	68.0			1.0		.366	.950		
	624	82.0			1.8		.366	.950		
	625	100.0		20	1.8		.366	.950	.025	
	626	22.0		15	0.3		.200	.630	.020	
	627	68.0		15	0.6		.304	.840	.025	
	628	150.0		15	2.0		.366	.950	.025	
	629	33.0		10	0.3		.200	.630	.020	
	630	100.0		10	0.8		.304	.840	.025	
	631	220.0		10	2.0		.366	.950	.025	
	632	47.0		6	0.3		.200	.630	.020	
	633	150.0		6	0.6		.304	.840	.025	
3	634	330.0	5	6	2.0	0.01	.366	.950	.025	

SPECIFICATION CONTROL DOCUMENT

F REVISE

APPROVED / ISSUE DATE	HUGHES AIRCRAFT COMPANY CULVER CITY, CALIFORNIA	STANDARD 988500
PROCUREMENT SPECIFICATION NONE	CAPACITOR, FIXED, ELECTROLYTIC -- TANTALUM, SOLID ELECTROLYTE	PAGE 20 OF 21

DO NOT SCALE

LIMITS UNLESS OTHERWISE SPECIFIED: .XXX = ± .XX = ± X° = ±

* PREFERRED VALUES

[2] WITHOUT INSULATING SLEEVE

[3] WITH INSULATING SLEEVE

[4] SPECIAL LOW LEAKAGE NOT FOR GENERAL USE. NO INSULATING SLEEVE

PROCUREMENT BY HUGHES AIRCRAFT COMPANY IS LIMITED TO THE MANUFACTURERS LISTED HEREIN:

KEMET CO., CLEVELAND, OHIO (CODE IDENT. NO. 05397)

SPECIFICATION CONTROL DOCUMENT

APPROVED	ISSUE DATE	HUGHES AIRCRAFT COMPANY CULVER CITY, CALIFORNIA	STANDARD 988500	REVISION F
PROCUREMENT SPECIFICATION NONE		CAPACITOR, FIXED, ELECTROLYTIC -- TANTALUM, SOLID ELECTROLTYE	PAGE 21 OF 21	

1. SCOPE

1.1 This addendum covers additional requirements and tests for solid tantalum capacitors that have been manufactured to the Hughes Aircraft Company document 988500.

1.2 Purpose. The primary purpose of this addendum is to provide long term test data correlated to each part, by serialization, to help select the parts with the highest probability of survival in long life spacecraft.

2. APPLICABLE DOCUMENTS

2.1 The following document, of the latest issue in effect, shall apply to this specification to the extent specified herein:

HUGHES AIRCRAFT COMPANY

988500 Capacitor, Fixed, Solid Tantalum

3. REQUIREMENTS

3.1 General. All parts supplied to this addendum shall have been manufactured to meet the requirements specified in the Hughes Aircraft Company document 988500.

3.2 Supplementary Requirements

3.2.1 Seal. The devices shall show no evidence of leakage when subjected to the test specified in 4.2 of this addendum.

3.2.2 Serialization. All capacitors selected from the manufacturer's lot of parts shall be distinctively serialized in a manner that will provide individual identity for every capacitor. All component data supplied in accordance with this addendum shall be identified by this capacitor serial number.

3.2.3 Extended Power Aging. After completion of the extended power-aging test described in 4.3 of this addendum, all the devices tested, including obvious defectives, shall be shipped to Hughes Aircraft Company. In addition, the data obtained shall be submitted as specified in 4.4 of this addendum.

3.2.4 Data Submittal and Certification. The requirements for data submittal and certification indicated in 988500 are replaced completely by those contained herein. The data and certification shall accompany the shipment of parts, and the form, content and procedures shall be as indicated in 4.4.

4. TESTS AND PROCEDURES

4.1 Sequence of Events. The sequence of events shall follow tht order shown in Table I. The table includes the screening tests of 988500, except that the sequence is now compatible with the supplementary requirements.

TABLE I

TESTS AND PROCEDURES

(REPLACES THE SCREENING TESTS OF HAC 988500)

NUMBER OF SPECIMENS	TEST OR PROCEDURE	REFERENCE PARAGRAPH		DATA TO BE SUPPLIED
		REQ	TEST	
All	Temperature Cycling	--	4.5.6*	None
	Seal	3.2.1	4.2	Attributes
	Apparent Failure Rate	3.2.6*	4.5.5*	Graphs, etc.
	Serialization	3.2.2	--	None
	D-C Leakage	3.1 (b)*	$\boxed{1}$	Variables
	Capacitance	$\boxed{1}$	$\boxed{1}$	Variables
	Dissipation Factor	$\boxed{1}$	$\boxed{1}$	Variables
	Workmanship	3.2.7*	4.5.7*	X-Ray negatives
	Extended Power Aging	3.2.3	4.3	Variables
--	Data Submittal	3.2.4	4.4	--

$\boxed{1}$ Applicable paragraph per MIL-C-26655

*Paragraph number per HAC document 988500

4.2 Seal. The capacitors, while at room ambient temperature, shall be immersed for a minimum of one minute in oil or water maintained at a temperature of 90° ±5° C. (See 3.2.1 of this addendum.)

4.3 Extended Power Aging. All capacitors shall be subjected to rated d-c voltage applied continuously for 1,000 hours, +100 hours, -20 hours. The test temperature shall be +65° ±3° C, except that cycling shall take place as follows: The oven shall be turned off five to seven times a week, each off period being five to seven hours. Measurements shall be made as follows: The d-c leakage shall be measured at +65°C, initially (two to four hours), at approximately 500 hours, and within two hours before removing the applied voltage. At the completion of the test, the capacitance, dissipation factor and d-c leakage shall be measured at room temperature. (See 3.2.3 of this addendum.)

4.3.1 Rejections. There are no rejections as a result of the extended power aging test; all parts, whether deemed defective or not, are the property of Hughes Aircraft Company.

4.4 Data Submittal and Certification. At least three copies each of the data and lead certification shall be placed in an envelope or separate container from the parts. The envelope shall be identified by the Hughes purchase order number.

4.4.1 Lead Certification. The manufacturer shall prepare a certified statement identifying the lead material, nominal diameter and finish, covering similar parts in the shipment.

4.4.2 Data Content. The data shall include the following:

a. Measurements of d-c leakage, capacitance, dissipation factor and the graphs of apparent failure rate obtained during the tests of Table I.

b. X-ray negatives, serialized, including those for parts removed from the lot.

c. The results of the seal test expressed in quantity tested and quantity rejected.

4.4.3 Data Format. The arrangement of the report shall be at the discretion of the manufacturer, but shall incorporate the following guidelines:

a. A cover sheet shall include the Hughes part number(s), the Hughes purchase order number and the date testing was completed.

b. The contents shall include a summary of the results, showing how many were tested, how many were rejected and in what test, and how many were shipped or returned to stock, etc. The calculated apparent failure rate from the screening tests shall be included in this summary.

c. Data for discrepant parts shall be encircled.

d. Test conditions under which the data was taken shall be briefly referenced (e.g., capacitance at 12 volts dc, 1 volt - 120 cps).

e. Clarifying notes shall be used to help explain any unusual behavior or procedure. (See 3.2.4 of this addendum.)

Critical Components

Critical component test plans are in final review and will be submitted shortly.

Test Plans and Specifications

Minor Control Item In-Process Test Specifications and Major Control Item Test Plans are being written in conformance with Project Bulletin 2, which establishes the format and certain visual and mechanical tests to be performed.

HUGHES

HUGHES AIRCRAFT COMPANY

SPACE SYSTEMS DIVISION

PROJECT BULLETIN

Subject: CONTROL ITEM TEST SPECIFICATION FORMATS (Revised)

No. 2 9/26/63

ADVANCED SYNCOM

This Project Bulletin provides standard formats for Advanced Syncom control item test specifications, and establishes certain tests to be performed as part of the tests.

The specifications should be written in general compliance with the attached formats. A test data sheet will be provided as in the Syncom Program; it will have places for noting compliance with the visual and mechanical inspection tests before the unit is closed or foamed. Spaces are to be designated for Quality Control stamp on visual, mechanical, and electrical tests. It is intended that the unit specifications show all the test requirements; deviations will be authorized as required.

A space will be provided in the data sheet for noting a Failure or Trouble Report number.

Advanced Syncom test procedures follow the following basic concepts:

1. Most minor control items will not have qualification test requirements or requirements for environmental exposures as part of acceptance tests. If the responsible engineering organization feels that environmental exposures are needed (even though not a contract requirement), these exposures should be made a part of the specification.

2. Major control items and selected minor control items will require qualification tests (Y2 hardware). Serial numbered items which will be installed in spacecraft will not require environmental exposures as a part of acceptance tests; serial numbered items that will be flight spares will require environmental exposures as part of acceptance tests.

Specific nomenclature has been set up contractually for the names of test specifications in order to distinguish the specifications which need NASA approval from those that do not: "In-Process Test Specification" will be used to identify specifications that do not require NASA approval; "Test Plan" will be used to identify specifications which require NASA approval.

Paul E. Norsell

P. E. Norsell, Manager
Systems Development
Advanced Syncom

Minor Control Item In-Process Test Specification

1.0 Scope: This specification covers unit__________(name and part number).

2.0 Applicable Documents: (Include issue date and revision letter with date).

3.0 Requirements: The (name) shall perform as follows: (List all performance characteristics with greatest emphasis on inputs and outputs which are to be tested and measured. The unit design has already been justified through design reviews, and system operations will be covered in system specifications, so these areas should not be included here. Adjustments necessary to accomplish any in-process test may, for example, I-F strip alignment procedures.)

4.0 Quality Assurance Provisions: Acceptance tests are the only required tests and shall consist of the following:

4.1 Visual-Mechanical Tests: The __________unit shall be inspected in accordance with the requirements of Specification 475000-607, "Visual-Mechanical Inspection Requirements for Control Items".

4.2 Performance: (Be brief; provide a test for each performance requirement given in Section 3. It is not necessary to repeat the performance requirements, but they may be stated for completness. Measurements and tolerances should be repeated on a data sheet. Specify detailed procedures and test equipment as required.)

4.3 Environmental Tests: (Specify if used).

5.0 Packaging: The________unit shall be delivered in a container which will provide adequate protection in handling, storage and movement. (Or list a drawing number or standard package which will do the above.) Plastic caps provided for protection of connectors must be in place.

6.0 Notes: (A sample data shall be provided for recording all test results. It must include space for checking the completion of the visual-mechanical tests of Paragraph 4.1, and have provision for a Quality Control inspection stamp after each test.)

Major Control Item Test Plan

1.0 Scope: This specification covers__________(name and number).

2.0 Applicable Documents: (Include issue date and revision letter with date).

3.0 Requirements: The (name) shall perform as follows: (List all performance characteristics with greatest emphasis on inputs and outputs which are to be tested and measured. The unit design has already been justified through design reviews, and system operations will be covered in system specifications, so these areas should not be included here. It is assumed that adjustments are not to be made on Major Control Items in acceptance testing. Out-of-tolerance performance will result in rejection of the unit and a failure report being written.)

4.0 Quality Assurance Provisions: Tests shall consist of the following types:

A. Acceptance tests for units to be installed in spacecraft.

B. Acceptance tests for flight spare units.

C. Qualification tests, for "Y-2"units.

4.1 Acceptance Tests for Units to be Installed in Spacecraft: The tests shall consist of the following:

4.1.1 Visual-Mechanical Tests: The__________unit shall be tested in accordance with the requirements of Specification 475000-607, "Visual-Mechanical Inspection Requirements for Control Items".

4.1.2 Performance: (Be brief. Provide a test for each performance requirement given in Section 3. It is not necessary to repeat the performance requirements, but they may be stated for completeness. Specify detailed procedures and test equipment as required.)

4.2 Acceptance Tests for Flight Spare Units: Tests shall consist of the following tests in the order shown:

4.2.1 Visual-mechanical and performance tests in accordance with Paragraph 4.1.1 and 4.1.2.

4.2.2 Environmental tests in accordance with (475000-602. "Environmental Requirements for Flight Spare Acceptance Tests of Major Control Items and Selected Minor Control Items"; or, if vibration tests will be performed on a spacecraft structure, reference 475000-603, "Spacecraft System Acceptance Test Plan", for vibration tests).

4.2.3 Repeat tests of 4.2.1.

4.3 Qualification Tests for "Y-2" Units: Tests shall consist of the following tests in the order shown.

4.3.1 Visual-mechanical and performance tests in accordance with Paragraphs 4.1.1 and 4.1.2.

4.3.2 Environmental tests in accordance with (475000-601. "Environmental Requirements for Qualification Tests of Major Control Items and Selected Minor Control Items"; or, if vibration tests will be performed on a spacecraft structure, reference 475000-604, "Spacecraft System Qualification Test Plan").

4.3.3 Repeat tests of 4.3.1.

5.0 Packaging: The____________shall be delivered in a container which will provide adequate protection in handling, storage and movement. (Or list a drawing number or standard package which will do the above.) Plastic caps provided for protection of connectors must be in place.

6.0 Notes: (Provide a sample data sheet for recording all test results. The data sheet must include space for checking the completion of the Visual-Mechanical tests, and have provision for a Quality Control Inspection stamp on each test.)

OSM AND BENDIX RF CONNECTORS

The Bendix and Omni Spectra line of miniature RF connectors are presently being evaluated. Previously selected connectors had the following problems:

1) Galling of mating threads – aluminum components showed excessive wear under normal number of mating and unmatings.

2) Coarse mating thread – connectors were unmating during vibration.

3) Grounding shields – the shields could not be grounded securely to the shells.

4) Noncaptivated contacts – the center contacts were being either pushed in or pulled out on panel or bulkhead jacks.

5) Ease of assembly – the connectors had many components and were relatively difficult to assemble.

Bendix and Omni Spectra connectors eliminate these problems by the following methods:

1) The use of stainless steel for shell material decreases thread wear and galling.

2) Finer mating threads discourage uncoupling due to vibration.

3) These connectors provide reliable grounding of shields by soldering to metal ferrule.

4) All bulkhead and panel jacks have captivated contacts.

5) Fewer components minimize assembly problems.

The Bendix and Omni Spectra series have these characteristics:

Impedance:	50 ohms
Cable:	RG-55B/U or teflon RF 142/U for OSM type RG-178/U for OSSM type
VSWR:	1.1:1 over a range of 2 to 10 gc
Material:	Shell, stainless steel; dielectric, teflon
Finish:	Gold plate per MIL-G-45204
Size:	1/4 size and weight of BNC type environment resistant

Preliminary specifications are being drafted and two sources are specified. The Bendix and Omni Spectra connectors are intermateable. Detailed information on the mating faces has been submitted by both vendors and thus intermateability verified. All materials and finishes will be space-approved. Samples for testing have been ordered from both vendors and testing will start in approximately 3 weeks.

Figures 6-1 and 6-2 show the connectors, both apart and mated. Figure 6-2 shows the means by which the contact in the female jack is captivated to prevent motion when the male plug is inserted.

MATERIALS AND PROCESSES

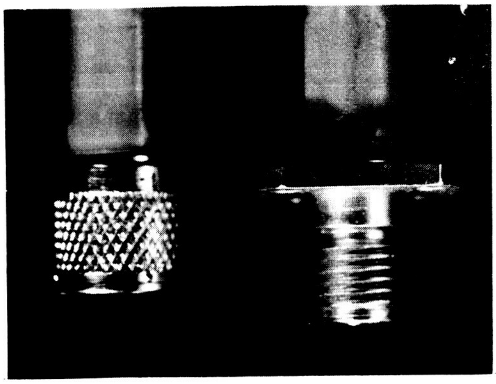
An optimum fabrication technique for the solar array has been tentatively chosen. The construction of the substrate incorporates 0.500-inch thick aluminum honeycomb core, 1/8-inch cell, 0.0007-inch foil. Faces are each three-ply No. 112-Volan A (each 3 mil) glass fabric, impregnated with an epoxy resin system of moderate thixotropy to assure uniform filleting at the core-facing interface. To hold weight to a minimum, the convex (outer) face is only two ply at the time of substrate fabrication. As will be explained, the third ply is applied during the cell attachment process.

The substrate is fabricated in a female aluminum lay-up tool (Figures 6-3 through 6-6). The 0.5-inch high nails on the mold surface represent the substrate periphery, and permit net fabrication (no trimming required). Edge closure is accomplished by cutting the bottom ply of fabric (ply against mold surface) approximately 1 inch oversize in all directions. This ply is then lapped over the top ply of the inner (concave) face. The completed substrate is then heat-cured under vacuum pressure.

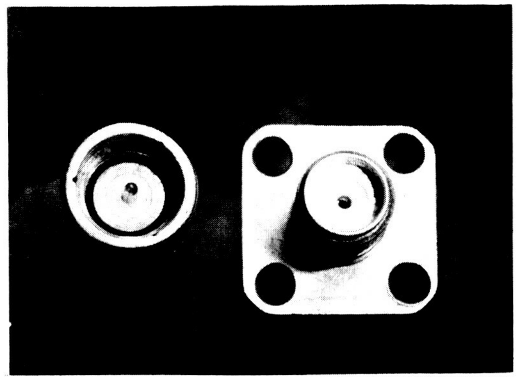
The solar cell strings (each string consists of 3 cells in parallel by 62 cells long) are attached to the substrate as follows:

One ply of 3-mil glass fabric slightly larger than the cell string is impregnated with the epoxy adhesive. This is located properly on the prepared substrate. The cell string is then positioned and positive pressure exerted by means of a clamped, rubber-faced hold-down pad.

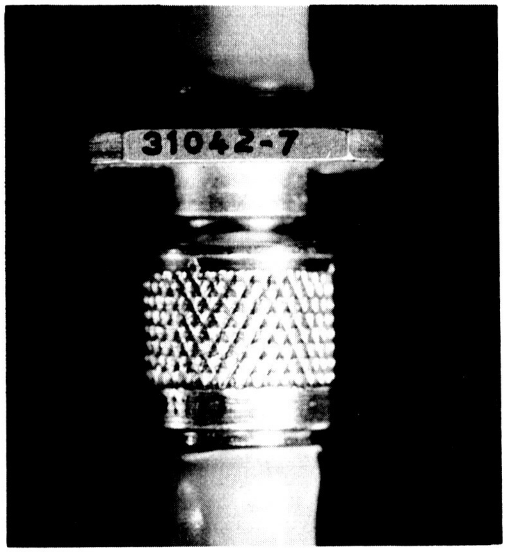
Solar array reliability is significantly improved by these processes. The unique edge-closure permits "net" fabrication which eliminates trimming and the need for the edge-fill putty previously used; the result is an increase in substrate uniformity and reliability. The cell bonding system provides a reinforced bond line, the optimum condition to resist thermal and other environmental stresses. Also, adhesive weight is virtually eliminated since the reinforced bond line becomes the integral third ply of the outer face. This technique also provides uniform bond line thickness, which is important in assuring uniform stress distribution. The finished panel is shown in Figures 6-7 and 6-8.



a) Side View



b) End View



c) Mated

Figure 6-1. Bendix Connectors

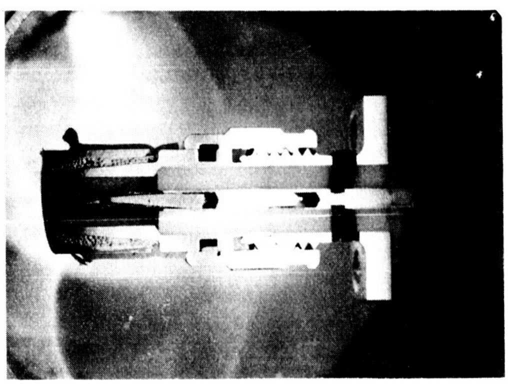


Figure 6-2. Sectional View of Mated OSM Connectors

Figure 6-3. Aluminum Cleaning Tool for Solar Panel Substrate Fabrication

Figure 6-4. Inserting Glass Cloth Into Tool

Figure 6-5. Inserting Honeycomb Into Glass-Cloth Lined Tool

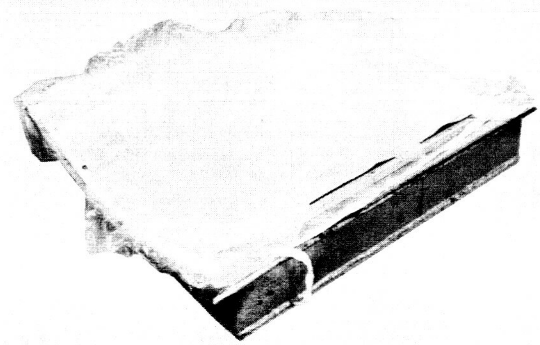


Figure 6-6. Solar Panel Fabrication Preparation Prior to Vacuum Oven Care

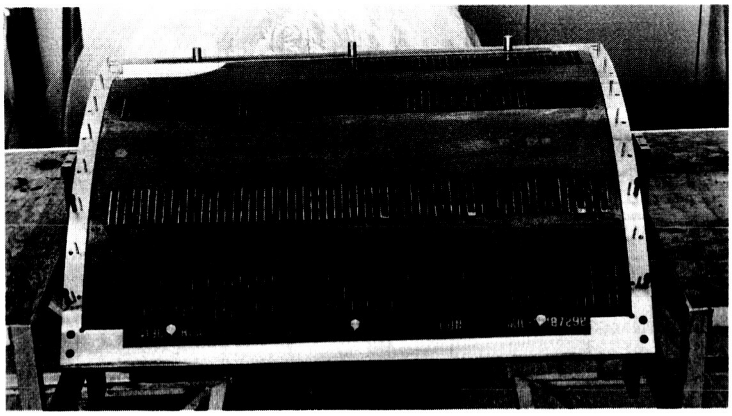


Figure 6-7. Solar Cells Being Mounted on Solar Panel Substrate

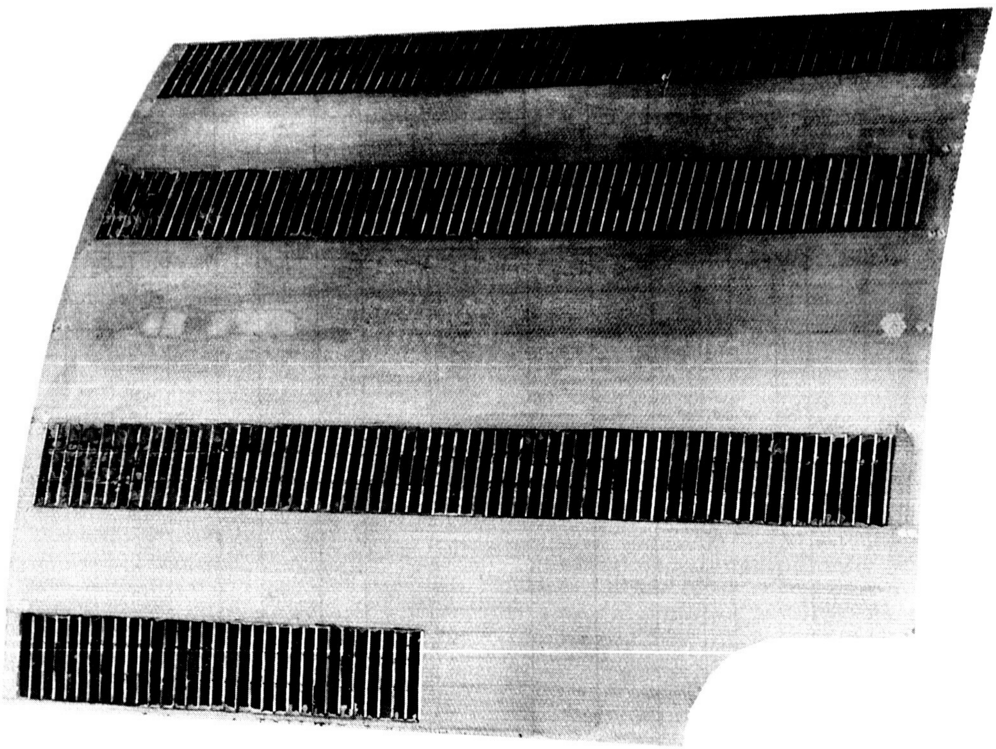


Figure 6-8. Closeup of Partially Completed Solar Panel

Traveling-Wave Tube Potting Material

As previously reported, a potting material with significantly greater high temperature capabilities has been developed. Its only drawback is its outgassing, which could induce undesirable physical degradation. Hermetically sealing the potted portion of the tube is therefore been considered, and a quantity of the new material has been supplied to Microwave Tube Division, where several collectors will be potted and subjected to thermal-vacuum tests.

Solar Cell Adhesive Program

Thermal-vacuum cycling tests on an improved solar-cell-to-substrate adhesive have begun. These tests are being conducted at a pressure of approximately 10^{-7} Torr with automatic cycling from +100° to -100° F and from +260° to -320° F at a rate of 20 deg/min. Test samples consist of solar cells without cover glasses bonded to small pieces of the epoxy-glass fabric faced aluminum honeycomb substrate. The adhesive is a modified epoxy system which has survived rigorous screening tests (thermal shock, repetitive from +260° to -320° F, and vacuum exposure at 260° F and 10^{-7} Torr for outgassing determination).

Interface Structural Cone

A tentative composite of materials has been considered for use in the construction of a dielectric structural cone at the Agena D/Advanced Syncom interface. Until stress analyses are available to influence composition and construction, it is planned to use fiberglass honeycomb core reinforced with epoxy resin-impregnated S-994 HTS glass fibers in a bidirectional bias wrap. Top and bottom ring attach methods are currently being considered.

7. SPACECRAFT SUPPORT EQUIPMENT, RELATED SYSTEM TESTS, AND INTERFACES

GROUND CONTROL EQUIPMENT DESIGN AND FABRICATION

Communications Panel

Transponder Test Panel

Assembly of the transponder test set for Advanced Syncom has been detailed. It is planned that the complete test position will include five bays of relay rack mounted equipment. The specially designed equipment (non-commercial items) and most of the spacecraft hardware will be installed on three chassis, each of which will be attached to a standard 7-by-19-inch panel suitable for rack mounting. Fabrication of the first chassis is approximately 80 percent complete; most of the commercial test equipment has been received and is ready for installation into the relay racks. The block diagram of the Advanced Syncom transponder RF test panel has been revised (Figure 7-1).

The bandpass filter on the output side of the balanced modulator is being redesigned to optimize compactness. The circuit configuration will remain the same. The two 12-db gain amplifiers on the output side of the filter have been combined into a single 15-db gain amplifier.

A quadrature phase detector has been added to drive a meter that provides a visible means of phase lock. A discriminator has also been added at the output of the frequency translation phase modulator so that video output of the modulator may be compared to input for test purposes.

Synchronous Controller

During this period, final equipment block diagrams were released for the synchronous controller (Figure 7-2) and the synchronous controller auxiliary (Figure 7-3). The detailed logic design of this unit is nearly complete, and circuit design has been started. Panel layout has been developed and is undergoing final evaluation.

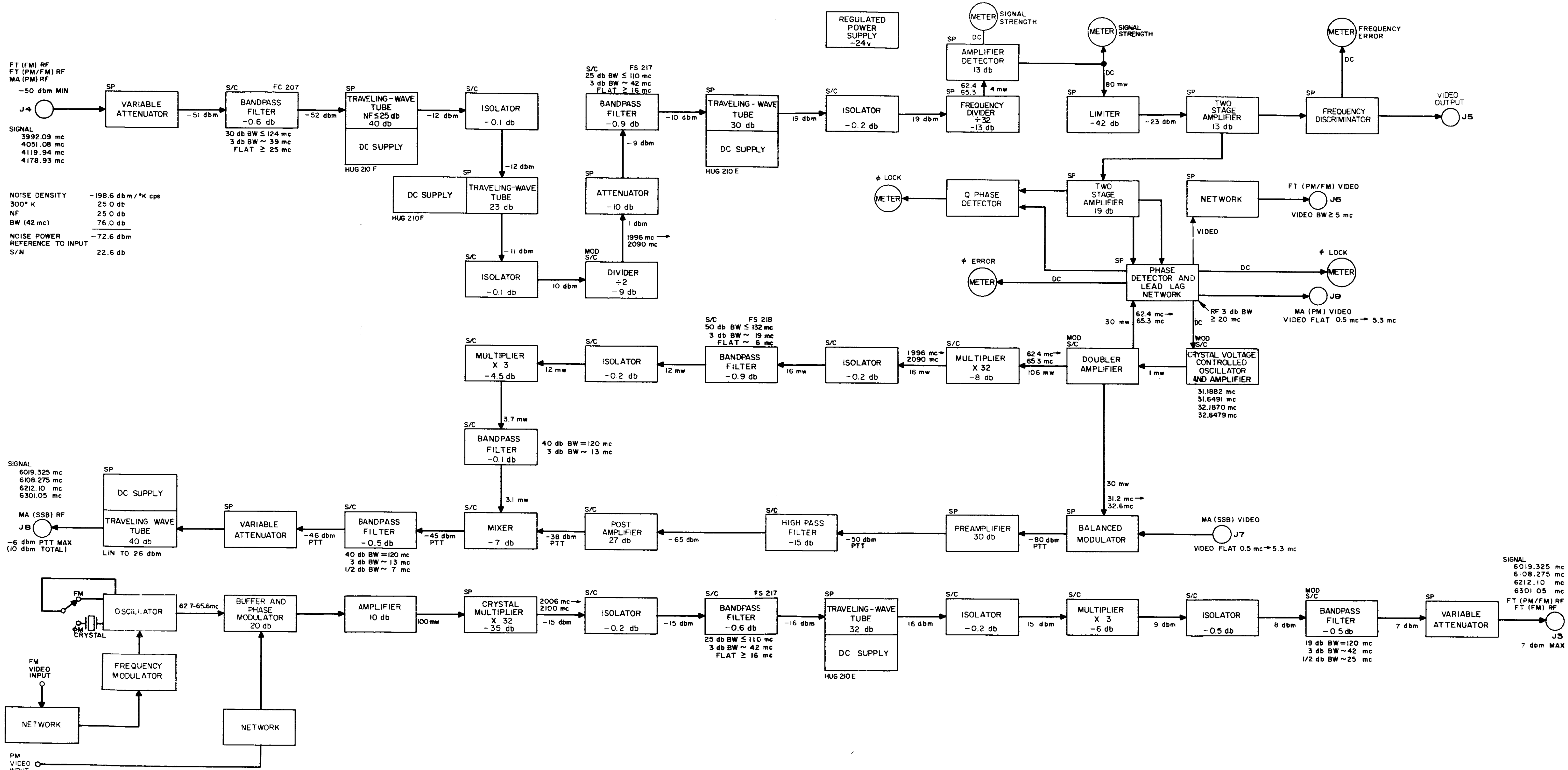


Figure 7-1. Revision of Block Diagram of Advanced Syncom Transponder Test Set

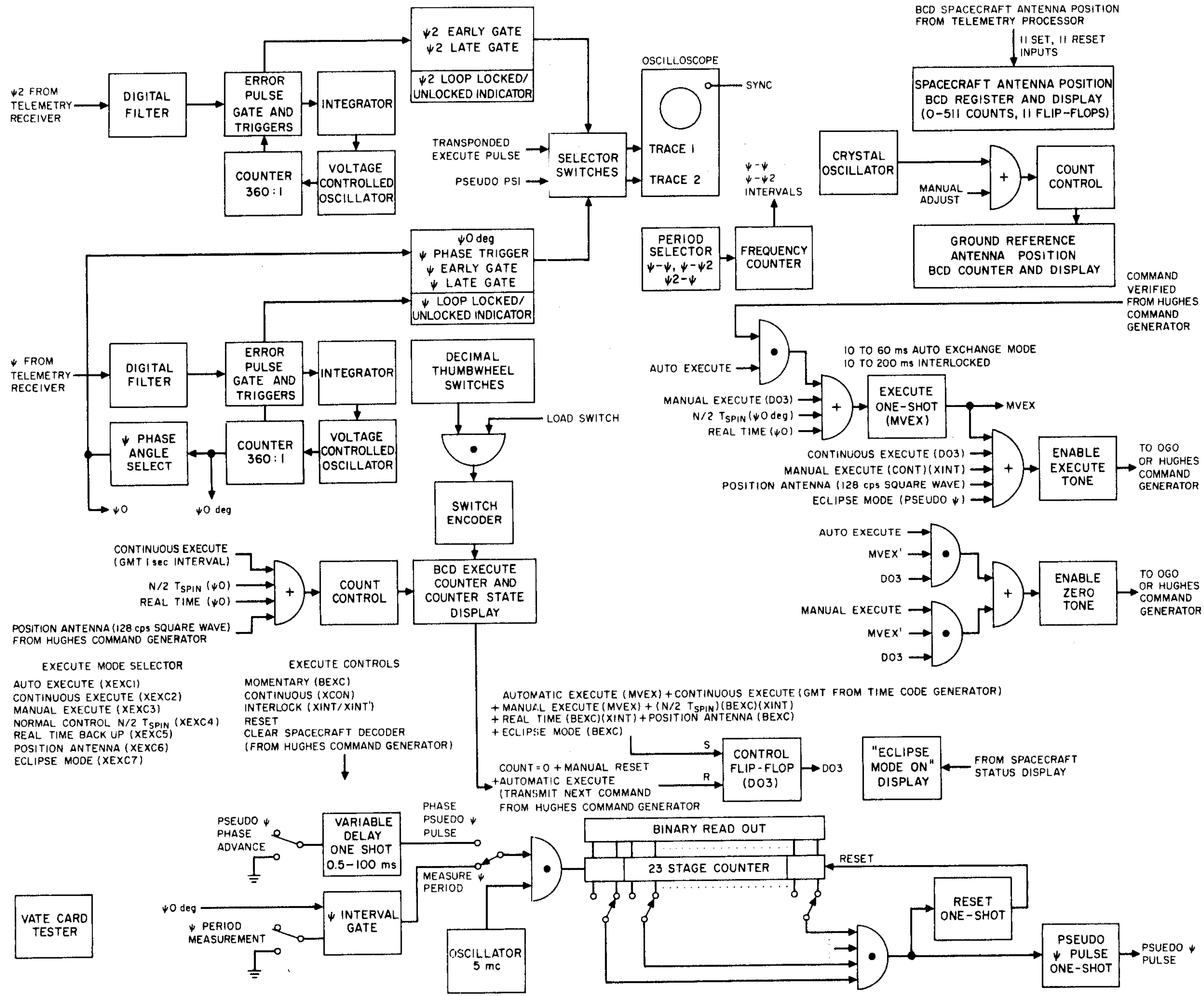


Figure 7-2. Synchronous Controller

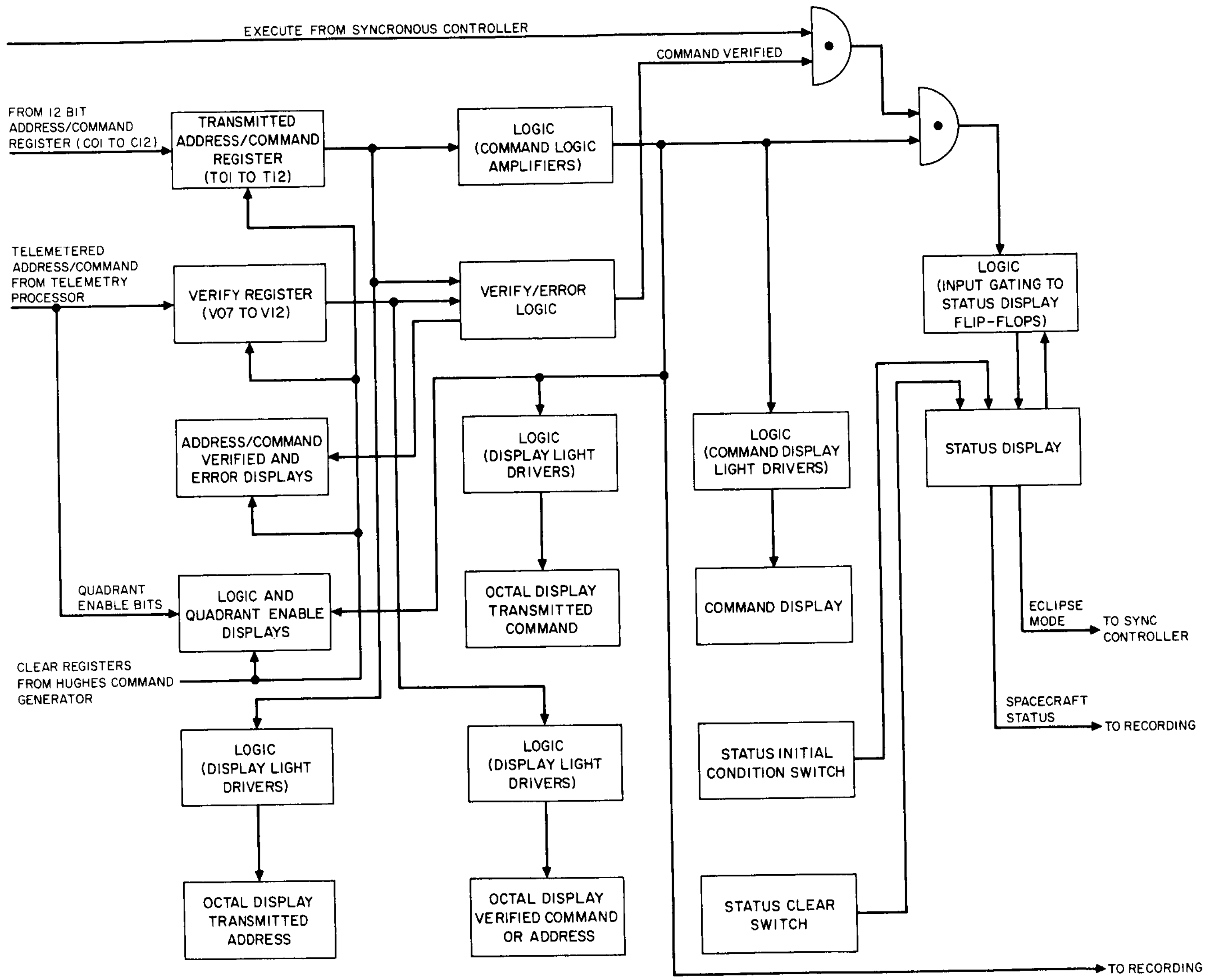


Figure 7-3. Synchronous Controller Auxiliary

8. SPACECRAFT HANDLING EQUIPMENT

WEIGHT AND BALANCE AND MOMENT OF INERTIA EQUIPMENT

A combination weight, center of gravity, and moment of inertia fixture is in detail design stage and progressing on schedule. The fixture consists of an aluminum frame attached to the spacecraft that has provisions for attachment of suspension wires; moment of inertia measurement is made using the bifilar torsional pendulum method. When the spacecraft is suspended from load cells, weight and center of gravity location may be determined. Measurements in the roll, as well as the pitch and yaw axes, may be made.

SYSTEM TEST AND SPIN FIXTURE

Design of the spin fixture is in progress. A drive unit based on the use of 1-1/2-hp US motors "varidrive" is being developed. A slip ring unit is being integrated into the main shaft assembly.

MOBILE ASSEMBLY FIXTURE

Design of the mobile assembly fixture was completed and released. The spaceframe is attached to a cantilever arm which may be rotated and secured in any convenient working position. Rotation is supplied by a hand-operated worm gear drive. The arm is supported by a sturdy steel tubular frame. Brake equipped casters provide mobility within the work area and allow the fixture to be secured in any desired location.

BALANCING MACHINE

Design layouts and specifications for the "make" version were released. Statement of work and procurement specifications for the "buy" version are in preparation.

ASSEMBLY TOOLING

Design of aft assembly tooling has been initiated and is approximately 60 percent complete.

9. PROJECT REFERENCE REPORTS

J. B. Beaumont, "Trip Report, 4 September 1963, NASA Lewis Research Center for LMSC Advanced Syncom Follow-On Study Final Report Presentation," IDC, 12 September 1963.

G. R. Blair and D. Horwitz, "Advanced Syncom Material Radiation Properties," IDC, 8 September 1963.

D. T. Dupree, "Master Index, Physical Ground Support Equipment, Advanced Syncom," 26 August 1963.

S. Fienberg, "Preliminary Release, Advanced Syncom Connector Pin Terminations," 17 September 1963.

S. Fienberg, "Location of Quadrant Connectors," IDC, 27 September 1963.

P. J. Fisher, "Advanced Syncom System Test Equipment Wiring Specification," 29 August 1963.

P. J. Fisher, "Revised Spacecraft Access Point List," IDC, 3 September 1963.

D. L. Frislie, "HP for the Assembly of Point-to-Point Soldered Electronic Modules," IDC, 12 September 1963.

L. A. Gustafson, "Solar Array Output Immediately After an Eclipse," 17 September 1963.

J. G. Lotta, "Advanced Syncom Mass Properties Data Configuration 3 SP Plus 2230," IDC, 3 September 1963.

J. G. Lotta, "Analysis of Gisholt Vertical Balancing Machine for Advanced Syncom," IDC, 6 September 1963.

J. G. Lotta, "Advanced Syncom Mass Property Data, HSX-302-T2," IDC, 10 September 1963.

J. G. Lotta, "Advanced Syncom Mass Property Data Configurations 4 through 8," IDC, 17 September 1963.

P. E. Norsell, "Action Summary, Advanced Syncom Project Meeting, 3 September," IDC, 9 September 1963.

P. E. Norsell, "Action Summary, Advanced Syncom Project Meeting, 10 September 1963," IDC, 16 September 1963.

P. E. Norsell, Supplementary Information, NASA-GSFC-SII-002, "Procurement Specification for a Frequency Modulation Ground Transmitter," IDC, 12 September 1963.

P. E. Norsell, "General Description of the OGO Console," IDC, 12 September 1963.

S. T. Plants, "Advanced Syncom Power Supply Loads," IDC, 24 September 1963.

J. G. Read, "Advanced Syncom Wire Recommendations," IDC, 18 September 1963.

J. W. Vorndran, "Minutes of Design Review of Advanced Syncom Telemetry Encoder," 28 August 1963.

Project Bulletin No. 2, "Control Item Test Specification Formats," 5 September 1963.

Project Bulletin No. 3, "Vitramon 0.01 Microfarad Capacitors (988504-16, -32)," 5 September 1963.

Project Bulletin No. 4, "Placement of "OR" Gates Diodes in Series Regulators," 17 September 1963.

Project Bulletin No. 5, "Definition of Command System" (Revises and replaces Advanced Syncom Project Notice 18, Revision A), 18 September 1963.

Project Bulletin No. 7, "Approved Parts List" (Revises and replaces Advanced Syncom Project Notice No. 21), 24 September 1963.